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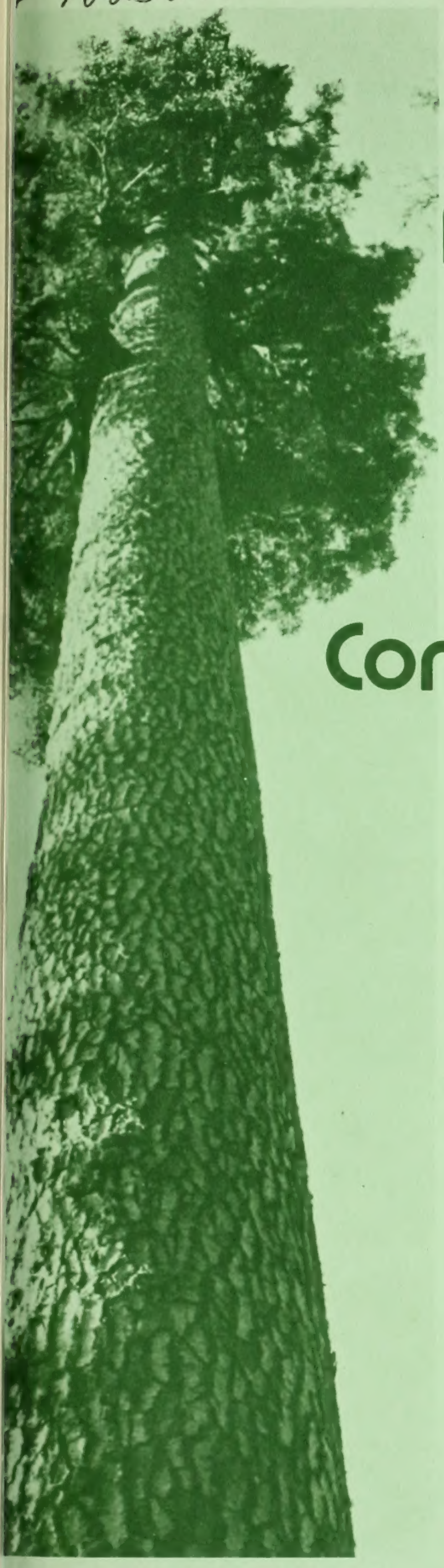

# Field and Computer Techniques for Stem Analysis of Coniferous Forest Trees

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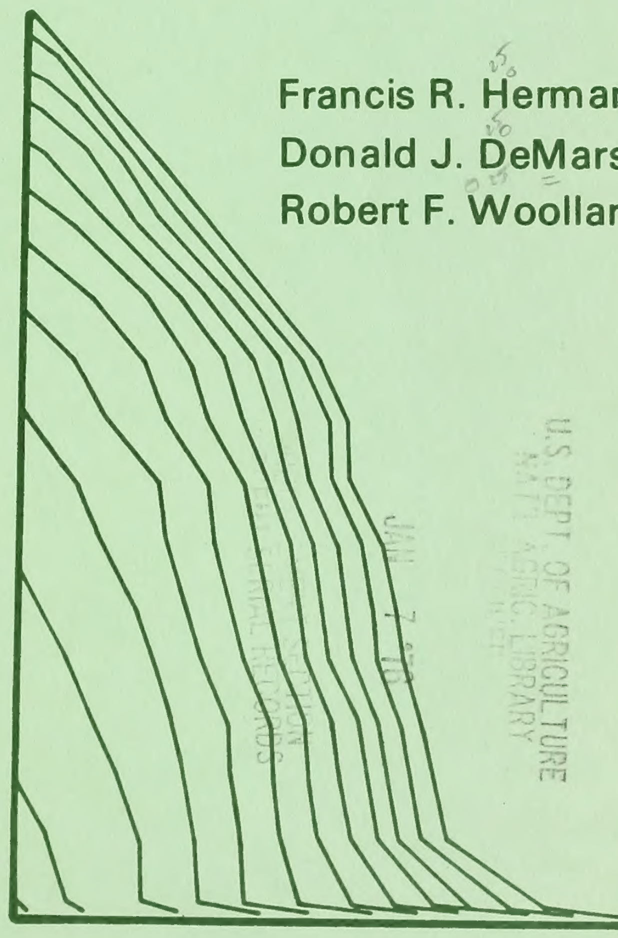



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# FIELD AND COMPUTER TECHNIQUES FOR STEM ANALYSIS OF CONIFEROUS FOREST TREES

## Reference Abstract

Herman, Francis R., Donald J. DeMars, and Robert F. Woollard
1975. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNW-194, 51 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Field and computer techniques for stem analysis adaptable to both young- and old-growth conifers are presented. Field instructions include a step-by-step explanation of tree cutting, sectioning, ring count, and measurement techniques. A computer program adapted to field techniques reproportions a tree's radial measurement data, calculates height-age-site index information, punches the reproportioned and height-age-site index information on cards, and plots height-age and stem profile graphs. These stem analysis techniques are adaptable to trees of any size up to 800 years old and to either American or metric measures. These instructions enhance the usefulness of the stem analysis research method in obtaining growth information for forest managers.

KEYWORDS: Stem analysis, age determination, ring measurement, data recording methods, old-growth conifers.

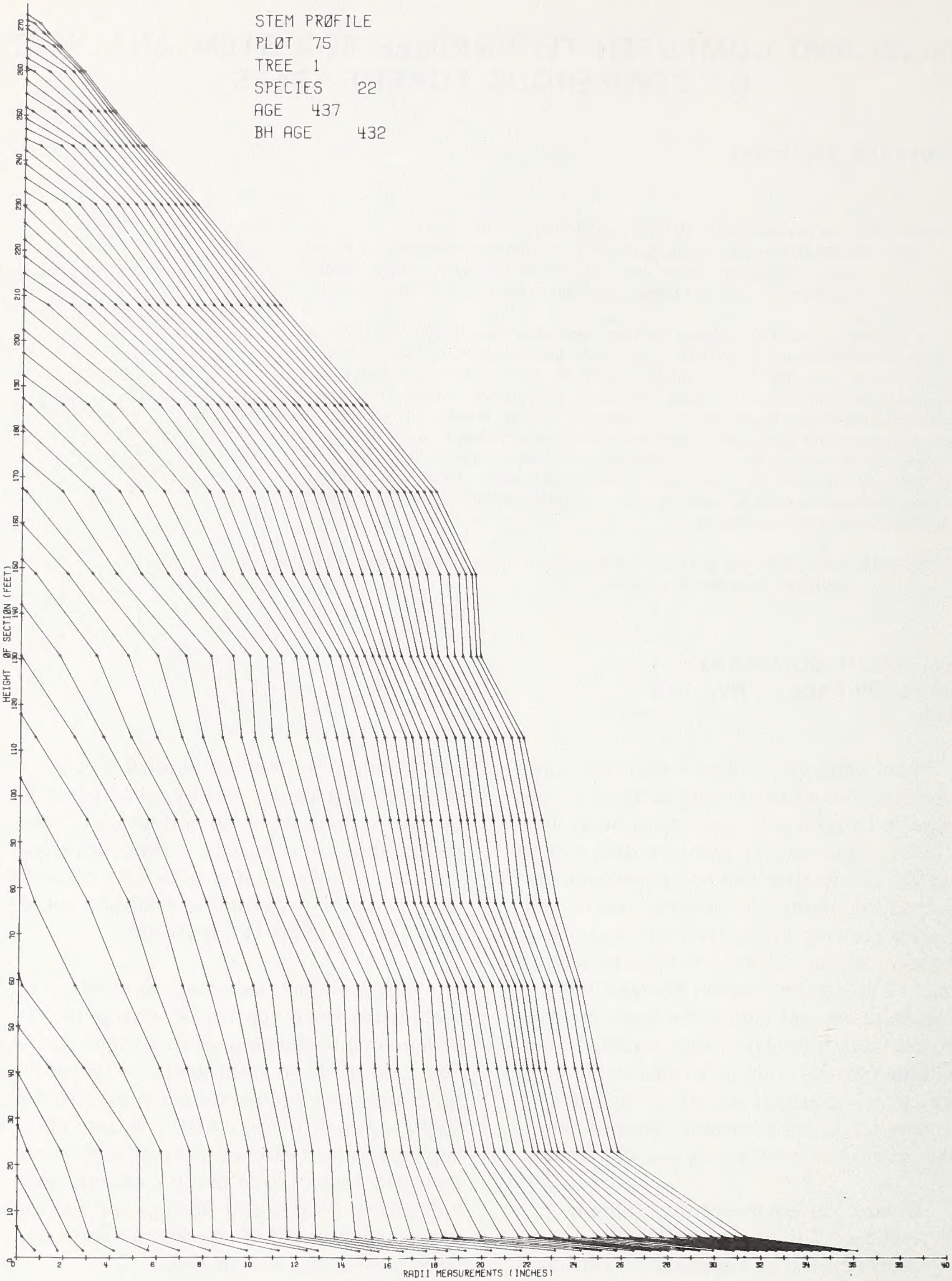
## RESEARCH SUMMARY
## Research Paper PNW-194
## 1975

Stem analysis studies within the upper-slope mixed-conifer forests of the Cascade Range in Oregon and Washington were begun in 1965. Objective of these studies was to develop site quality and comparative growth information among the several coniferous species growing in the true fir-hemlock forests. Work was done within the natural range of noble fir between Stevens Pass in Washington and McKenzie Pass in Oregon. Stem analysis was selected as a technique for developing productivity information because it permitted use of overmature trees to obtain information about growth of both young and old trees.

During the course of the studies, efficient methods of data collection and use were devised and applied. From that experience, detailed instructions of stem analysis field methods, including tree felling, sectioning, and measurement of sequential radial growth (SRG), are presented. Three different methods of collecting multiple-ring SRG data are explained. One method is used as an example to give the reader a complete set of instructions for field collection of data compatible for automatic data processing (ADP). Modification of both data collection and computer programing would be necessary for the other two methods.

Many old and new stem analysis techniques were applied in appropriate succession to develop efficient operations. The goal of these stem analysis techniques is to code and record data compatible for ADP. Output for that ADP consists of reproportioned SRG measurements, stem analysis graph (stem profile chart), and height-age graphs and listings for individual trees. Any or all of the output items may be selected on a single run.

Both field and computer techniques are adaptable to either the American or metric system of measurement--only minor change in programing is necessary for conversion.




*Computer-produced stem profile chart for noble fir with a breast-height age of 432 years.*

## Contents

# Introduction

To develop site quality and other growth information essential for proper management of the upper-slope true fir-hemlock forests of the Cascade Range in Oregon and Washington, the U. S. Forest Service and Oregon State University began stem analysis studies in 1965. This work was aimed especially at collection of growth data from old-growth noble fir[1/] for estimation of site index (DeMars et al. 1970, Herman and DeMars 1970). Noble fir stem analysis growth data also were used for comparison of methods of site index estimation (Curtis et al. 1974a); and associated Douglas-fir data were used in development of site index information, specifically for upper-slope Douglas-fir in the Cascade Range (Curtis et al. 1974b).

Species composition within the upper-slope mixed-conifer forests of the Cascade Range is complex. Radiolongitudinal data produced from these stem analysis studies are providing the first information about measured growth relationships among surviving old-growth dominant and codominant individual trees within and between defined habitats. With such a wide representation of different species--as many as 9 or 10 on each acre--considerable latitude is available for selection of a particular combination for managed stands. Comparative growth information has proved valuable in other mixed forest types (Deitschman and Green 1965, Green and Alley 1967, Carmean and Vasilevsky 1971) and will prove equally valuable in the Pacific Northwest.

Besides providing comparative growth information specifically for mixed conifers in the Cascade Range of Oregon and Washington, field and computer techniques presented in this paper are applicable to stem analysis of both young- and old-growth conifers regardless of where they grow. Furthermore, such techniques are adaptable to either the American or metric system of measurement--only minor change in programing would be necessary for conversion.

Natural forest stands containing noble fir are found in the Pacific Northwest Cascade Range roughly between Stevens Pass in northern Washington and McKenzie Pass in central Oregon (fig. 1). The area south of McKenzie Pass in the Willamette National Forest was excluded from the study to avoid confusing growth variation caused by hybridization with Shasta red fir. However, a few Shasta red fir and associated tree species were sectioned for comparative studies in southwestern Oregon. Table 2, appendix I, presents a list of the important upper-slope coniferous tree species with their assigned numerical computer codes.

Because few upper-slope forest stands of 150 years of age and younger were found in the Cascades, older trees were selected for study. Our stem analysis technique permitted us to use overmature trees to obtain information on growth of both young and old trees. Furthermore, stem analysis as a technique was adapted to this growth-evaluation research because no uniform and random range of age classes existed throughout the noble fir range. Except for infrequent, scattered young-growth stands arising from some catastrophic event such as fire or windstorm, most stands were 200 to 400 years old.

The stem analysis approach has the inherent disadvantage of dependence among successive measurements on the same sample tree and presupposes that selected trees were always dominant

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1/ See table 2, appendix I, page 22, for scientific names of trees.

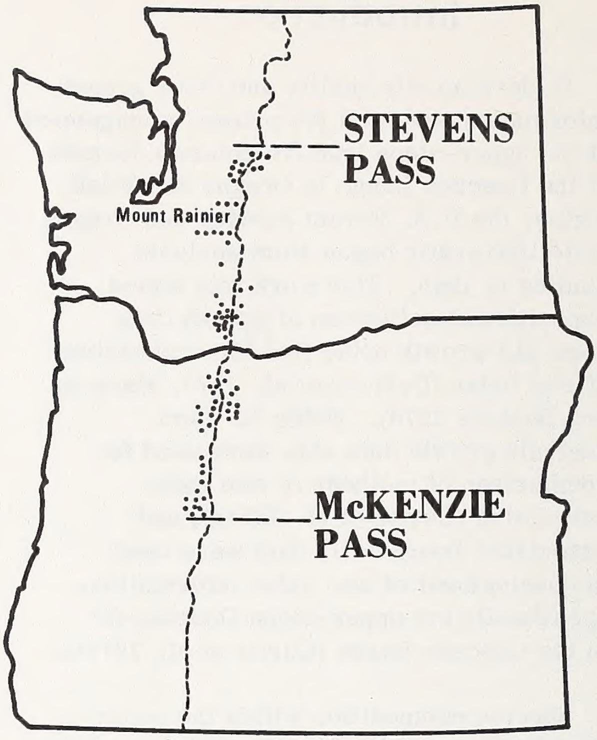


*Figure 1.--Stem analysis study locations within the natural range of noble fir in Oregon and Washington.*

throughout their lives (Schlich 1895, Dahms 1963). This disadvantage may or may not be important. During our quest for upper-slope noble fir and Douglas-fir site index information, occasional checks of heights of two to four dominant noble fir trees at selected ages at given locations showed no significant changes in dominance.

There are several advantages to the use of the stem analysis method. These have been discussed at length by several workers over many years. Curtis (1964) refers to much of that literature and points favorably toward the use of the method.

The disadvantage of dependence among successive measurements on the same tree can be minor compared with the disadvantages associated with the empirical method of attempting to span a site quality interval for a given species by selecting for measurement a great many representative temporary forest plots. Stem analysis provides a solution to the problem of unbalanced site selection over a wide range of ages because a uniform number of height observations always is available for any given age for all selected sites.

Even with such widespread species as Douglas-fir (McArdle et al. 1961) and western hemlock (Meyer 1937, Barnes 1962), research workers using stand data were not able to select equal numbers of stands for all ages over an equal number of potential growing sites. Beck and Trousdell (1973) discussed and demonstrated the effect of that problem of disproportional sampling of site and age.

Procedures for stem analysis of trees have been both briefly and comprehensively described in many basic and advanced forestry measurement textbooks and

bulletins at least as early as 1895 (Schlich). A complete description of stem analysis methods and uses in early American forestry literature was presented by Mlodziansky (1898). Detailed field and office procedures included use of such data to determine past and current volumes of individual trees. Many other references to early American forestry stem analysis methods and uses are given by Spurr (1952) and Turnbull.[2] Later references to the technique and one of the most complete contemporary descriptions of procedures are contained in a mensuration text by Husch (1963).

Our paper describes for the first time detailed and complete procedures, including collection of field data and use of that data, for stem profiles and height-age curves produced by Automatic Data Processing (ADP).

Objectives of this paper are:

1. To describe the field and laboratory procedures actually used in stem analyses.

2. To recommend field and laboratory procedures applicable to similar studies and forestry education exercises.

3. To present a stem analysis computer program with instructions for its use.

Techniques of field, laboratory, and computer operations presented in this paper are purposely detailed to furnish step-by-step instructions for those who wish to use our stem analysis procedures to develop site index information and secure stem profile data for growth comparisons and volume determinations.

[2] Kenneth J. Turnbull. Stem analysis techniques and applications and some studies of second-growth Douglas-fir in western Washington. Unpublished M. F. thesis, University of Washington, Seattle, 1958.

# Stem Analysis Field Methods

Hundreds of true fir-hemlock stands within the natural range of noble fir were visited. From these stands, study locations were selected. Habitat type and understory vegetation differentials[3] [4] at varying elevations and latitudes were bases for selection. Frequently, site continuums were selected--as from ridgetop to valley bottom.

## TREE SELECTION AND PREFELLING MARKING AND MEASUREMENTS

After each location was determined, the tallest dominant or codominant tree of each species (table 2, appendix I) present within approximately one-fourth acre was selected for stem analysis. Trees with obvious defects such as thin crowns, stag, forked, or broken tops, and bent and crooked stems were avoided, as were severely leaning or unbalanced trees. Rot indicators such as conks, catfaces, frost cracks, and abnormal stem swelling caused trees to be rejected. Any tree suspected of decay was "bored" at stump height with the rounded tip of the chain saw. Expelled wood fragments were monitored for rot. Trees with "brooms" in the crown, whether caused by dwarf mistletoe or some other disease, were taken if nothing else was available.

After trees were selected and before they were felled, they were circumscribed at stump and breast heights with spray

[3] Jerry F. Franklin. Study plan for development of a habitat type classification of the true fir-hemlock forests of the southern Washington Cascades. 51 p. Unpublished report, Forestry Sciences Laboratory, Corvallis, Oregon, 1962.

[4] Jerry Forest Franklin. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph. D. thesis, Washington State University, Pullman, 132 p. 1966.

paint, in planes at right angles to the vertical axes of stems. Stump and breast height diameters were measured with a diameter tape. Where information about stem cross-section eccentricity in relation to cardinal direction was desired, special stump and breast height stem marks were made before trees were felled. North and south (or east and west) cardinal direction stem exposures were marked with vertical spray paint lines (fig. 2). Analyses of cross-section eccentricity information are made separately from the same ring count and ring interval measurement data collected for height-diameter and height-age growth evaluations.

## TREE FELLING

Where possible, felling was done along contour--not over drainages or rock outcrops--to avoid excessive breakage. Felling into adjacent trees was avoided as much as possible to prevent hangups, severe breakage, and loss of candidate treetop. Stands with hemlocks were especially difficult to work within because the long crowns easily became entangled.

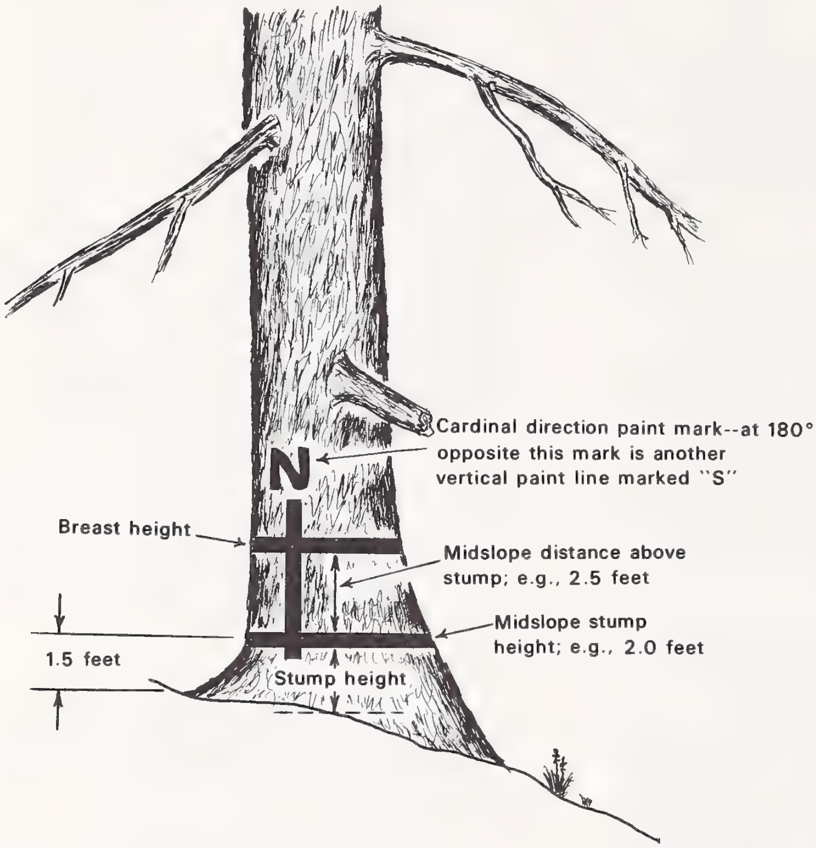


*Figure 2.--Diagram showing painted stump ring, breast high ring, and cardinal direction, or exposure reference marks.*

The stump was cut either 2 inches above or 2 inches below the stump ring mark, with care taken not to undercut across the stump mark. If the cut was below stump mark, the undercut left a flat surface on

base of upper stem section. If cut was above stump mark, the undercut left a flat surface on stump. The stump section was prepared for measurement by cutting through the painted ring. When slightly leaning or unbalanced trees necessarily were selected, special care in stump preparation was taken to avoid pulling long splinters of wood from the stem or stump. Back cut was always maintained parallel to undercut. Side cuts were made to prevent longitudinal "barber chair" splitting of the stem.

## TREE STEM REASSEMBLY AND MEASUREMENT

The tree was limbed from stump to top, including all broken stem parts. Before length measurements were taken, all broken stem pieces were matched to provide accurate information on stem length. Broken bark and wood patterns, wood grain patterns, and knot arrangements provided "keys" to accurate "reassembly." Broken pieces quite often were impossible to physically join together because of weight and displacement distances. Pressurized spray paint cans with a fine nozzle provided a good method of marking matching points on broken stems.

## TREE SECTIONING

All points on tree stem where sectioning cuts were to be made were marked with paint. Cuts were made at short log length intervals so they could be salvaged. Although actual measurements varied, the most satisfactory sectioning sequence for both salvage and good stem profile data was: stump height, 4.5 feet (1.37 meters) above ground (breast height); 9 feet (2.74 meters) above b.h.; then 18 feet (5.47 meters); 36 feet (10.94 meters); etc., by 18-foot (5.47-meter) increments to a 12-inch (30.5-centimeter) top. Sectioning above the 12-inch top was done at shorter invervals--6 to 10 feet (1.8 to 3 meters)--preferably centered near selected internodes. Where salvage of stem was not required, section cuts above breast height were made at individual discretion, but at *no* greater intervals than where salvage was planned. In addition to the sectioning points, cuts made at a point just below the base of the primary live crown in an area undistorted by branch swell provide information on stem form below and within the crown.

Section cuts were marked by use of a 100-foot steel tape graduated in feet and hundredths of feet. Average stump height was measured and zero end of the tape was placed at base of cut stem (allowing for the width of the stump section if taken from base of stem). Cumulative measurements of stem length were carried as shown in figure 3. Several methods of measuring length were tried. All were discarded in favor of the system shown in figure 3. Best accuracy and, of course, fewer rechecks of down trees were necessary when the cumulative-height-above-stump measurements were obtained before the stem was bucked and sectioned. Bucking of the stem before stem length and diameter measurements are taken is best avoided.

Yellowjacket Creek (1)
North Bend Ranger District
Snoqualmie National Forest (2)

Noble Fir 1 (4) Plot 75 (3)
Established 6/28/68 (5)
Felled 8/11/68 (6)

| Taped Section Intervals | Stump Height and Cumulative Height Above Ground | Diameter Outside Bark (12) | Diameter Inside Bark (14) | Single Bark Thickness Measurements | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Feet | Inches | Inches | Inches | | | | | | |
| Stump | (7) 1.5 | 74.9 | *72.90 (15) | 1.20 | 1.30 | 1.40 | 1.05 | 1.50 | 1.35 | Ave 1.30 |
| B.H. | 3.0 (8) | 65.8 | *62.66 | 1.75 | 1.55 | 1.15 | 2.10 | 1.40 | 1.45 | Ave 1.57 |
| 21.4 | 21.4 | 54.1 | 51.95 | | | | | | | |
| 39.4 | 39.4 | 52.4 | 50.05 | | | | | | | |
| 57.3 | 57.3 | 50.5 | 48.60 | | | | | | | |
| 75.4 | 75.4 | 48.6 | 46.50 | | | | | | | |
| (9) 93.4 | 93.4 | 47.5 | 45.20 | | | | | | | |
| (10) 18.0 | 111.4 | 46.6 | 43.60 | | | | | | | |
| 32.0 | 125.4 | Break (11) | | | | | | | | |
| 3.8 | 129.2 | 43.1 | *39.86 | 1.80 | 1.80 | 1.70 | 1.50 | 1.40 | 1.50 | Ave. 1.62 |
| 21.8 | 147.2 | *42.98 (13) | 39.40 | 1.40 | 1.50 | 1.55 | 1.95 | 2.15 | 2.20 | Ave 1.79 |
| 39.9 | 165.3 | 38.8 | 36.00 | | | | | | | |
| 46.8 | 172.2 | Break | | | | | | | | |
| 12.2 | 184.4 | *33.14 | 29.90 | 1.65 | 1.85 | 1.60 | 1.50 | 1.55 | 1.55 | Ave. 1.62 |
| 29.1 | 201.3 | Break | | | | | | | | |
| 5.1 | 206.4 | 25.1 | 22.36 | | | | | | | |
| 13.3 | 214.6 | Break | | | | | | | | |
| 3.9 | 218.5 | Break | | | | | | | | |
| 10.2 | 228.7 | *17.66 | 15.10 | 1.20 | 1.25 | 1.40 | 1.25 | 1.25 | 1.35 | Ave. 1.28 |
| 14.0 | 232.5 | Break | | | | | | | | |
| 6.8 | 239.3 | Break | | | | | | | | |
| 2.4 | 241.7 | 12.14 | 10.45 | | | | | | | |
| 10.1 | 249.4 | 9.12 | 7.80 | | | | | | | |
| 12.8 | 252.1 | Break | | | | | | | | |
| 4.9 | 257.0 | Break | | | | | | | | |
| 1.3 | 258.3 | 5.90 | 5.06 | | | | | | | |
| 5.9 | 262.9 | Break | | | | | | | | |
| 1.1 | 264.0 | 3.35 | 2.93 | | | | | | | |
| 2.9 | 265.8 | | | | | | | | | Old stem bend |
| 4.0 | 266.9 | 2.14 | 1.85 | | | | | | | |
| 4.6 | 267.5 | Break | | | | | | | | |
| 1.6 | 269.1 | 1.37 | 1.18 | | | | | | | |
| 2.3 | 269.8 | Break | | | | | | | | |
| 1.3 | (16) 271.1 | Tip | | | | | | | | |

(17) Elevation 2903 ft
(18) Slope 10 % Aspect (19) SE
(20) Clear length 121.5 ft. above stump
(21) Length to main live crown 121.5 ft. above stump
(22) Length to epicormic live crown 121.5 ft. above stump
(23) Crown position Dominant
(24) Total height 272.6 ft.

* Measurements in shaded circles are calculated--not directly measured.

*Figure 3.--Sample of field notes taken in waterproof field surveying book for tree measured before it was sectioned.*

Explanation of Field Notes (fig. 3)[5]

1. Plot name--from some local geographic feature or manmade structure such as Lower Cedar River, Humpback Mountain, Yellowjacket Creek, Carpenter Lookout Road, etc.
2. District and Forest.
3. Plot number.
4. Species and tree number.
5. Tree selection date.
6. Tree felling and sectioning (bucking) date.
7. Stump height above average ground level--stump cut was made 1.5 feet above ground on uphill side. However, *recorded* stump height above average ground level was at least equal to 1.5 feet. Usually it was greater because of sloping ground.
8. Cumulative stem length from zero (stump cut).
9. Tape "zeroed" at sectioning point, 93.4 feet above stump. If tape longer than 100 feet is used, "zeroing tape" usually is not required unless stem is broken.
10. Cumulative stem length from tape zero at 93.4-foot section.
11. "Break"--stem is broken at "32.0" from "93.4" tape zero point. Tape is "zeroed" again and cumulative measures continued to next stem "break," etc.
12. Diameter outside bark (d.o.b.) for stump and breast height obtained before tree was felled, and upper stem diameters obtained where bark was undamaged before felled stem was bucked.
13. Where bark was damaged at planned point of sectioning, d.o.b., where circled, was calculated; double of average of six bark thickness measurements was added to the peeled diameter of section. Measurements of bark thickness were taken at approximately 60° intervals on the adjacent, undamaged section cut and/or break. Each bark thickness measurement represents the thickest bark within that 60° arc on the stem at or near the section point. Where end of cut stem was used, a 6-inch rule was used to project undamaged bark surface to cut stem surface for measurement (fig. 4).

[5] No section at 9 feet above breast height was taken on this example because high quality of stem dictated salvage for peeler logs.

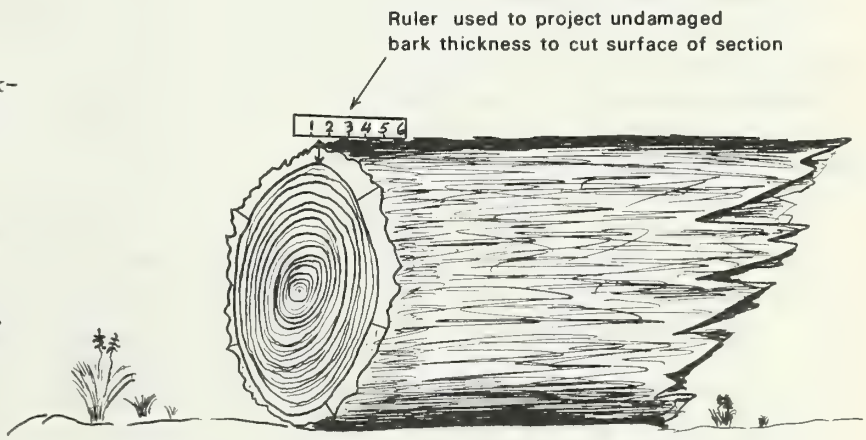


*Figure 4.--Six bark thickness measurements were taken at approximately 60° intervals around stem circumference on each section cut or break where d.o.b. could not be obtained because of bark damage.*

14. Diameters inside bark (d. i. b.), except where circled, were obtained by "slipping" bark from stem section. This is easily done during the early part of the growing season and soon after felling. Later in the growing season, all bark thickness was measured as described in point 13 because bark could not be easily and completely removed.
15. Diameters inside bark, where circled, were calculated as described in point 13 from double of average of six bark thickness measurements subtracted from d. o. b.
16. Total stem length above stump.
17. Plot elevation from barometric altimeter.
18. Average slope of plot area in percent.
19. Aspect expressed in quadrant or half-quadrant.
20. Clear length above stump--no limbs or knot indicators on bark to point specified. Small epicormic branches 1/4-inch or less in diameter were ignored in determination of clear length.
21. Length *to* base of live crown above stump--this is to base of primary or main live crown exclusive of all green epicormic or dead branches.
22. Length *to* base of live crown above stump as defined by beginning of epicormic branches often found on Engelmann spruce and occasionally Douglas-fir.
23. Crown position--"Dominant," "Codominant," etc.
24. Total tree height above average ground level. Each tree selected and felled for stem analysis provided its own individual measurement problems. Not all of the previously described measurement techniques necessarily were used on each tree. In practice, the most efficient combination of measurement techniques that provided accurate data was selected and applied as needed.

## DETAILED SECTIONING MEASUREMENTS, RING COUNTS, AND SEQUENTIAL RADIAL GROWTH MEASUREMENTS

1. Before actual sectioning:[6/]
   a. Diameter outside bark was measured at all designated sectioning points. Where bark was damaged or lost, diameters outside bark were taken at equal distances both ways along log from the section cutting mark and averaged (except at stump and breast height). When this distance was greater than twice the diameter at that point, the section d. o. b. was obtained by d. i. b. measurement and individual bark measurements from logs adjacent to section. (See explanatory information relative to fig. 4.)
   b. Cardinal direction upper-stem exposure marks (see fig. 2). Whichever felled stem exposure faces skyward--north, east, south, or west--dictates position of exposure reference marks across all felled stem section points before stem is bucked and sectioned. If tree is bucked before exposure marks are made, this information quite likely will be impossible to collect.

2. Sectioning:
   Cross sections (disks) 2 to 3 inches thick were cut at all marked stem section points where diameter was larger than 20 inches (fig. 5). Disks

[6/] If faller worked when measurement crew could not be present, many measurement problems arose. Trees were felled and bucked to length and transverse sections were cut before outside bark diameter and cumulative height measurements were taken. Inaccuracies in diameter and length measurements taken by untrained personnel negated efficiency otherwise derived. However, this type of assembly line production can be used if felling and bucking crews are *carefully* trained.

*Figure 5.--Cutting stem section disk from old-growth Douglas-fir.*

1 to 2 inches thick were taken from smaller diameter stem sections. Bark was removed completely for d. i. b. measurement. When only a partial section was available because of breakage or bucking difficulties, its diameter was estimated from other associated measurements. A partial section was only acceptable when it contained the pith and a complete radius with an acceptable or "representative" (reasonably normal) ring-growth pattern.

Trees having annual ring pattern destroyed by rot, of course, were rejected. However, where decay was encountered that had not completely obliterated the annual rings, thicker sections of 4 to 6 inches were cut. Decayed sections were carefully handled to prevent breakage. Sandwiching them between strips of 1/4-inch plywood eliminated breakage and loss of information. These later were carefully soaked in water and frozen to facilitate ring counts and measurements (Herman et al. 1972a, 1972b). Douglass (1928) described an efficient field technique which used a paraffin-gasoline solution to render decayed wood workable. His technique permitted immediate ring counts and sequential radial growth measurements.

3. Recommended ring counts and sequential radial growth measurements (fig. 6):

   If single ring counts and measurements are to provide data for stem profiles, data collection is relatively uncomplicated. However, if decadal, half-decadal, or other multiple ring measurements are to be taken, counts and sequential radial growth measurements must be taken in a specific manner to provide type of data desired.

   At least three different approaches to multiple ring counts are possible:
   a. If desirable to compare tree growth

*Figure 6.--Ring counting using large reading glass.*

of several trees at selected years in fixed sequence, multiple-ring count must begin at each section circumference and proceed toward the pith. After ring count is completed and ring intervals are marked for each section radius, sequential radial increment measurements are made from the pith and recorded on stem analysis ADP coding form (fig. 11, appendix I). For example, for a tree cut in 1973, decadal count and measurement would provide growth comparison at all section points for 1963, 1953, 1943, and so forth back through time at 10-year intervals.

b. If desirable to compare tree growth at even chronological decades, decadal ring count also must begin at section circumference and proceed toward the pith. However, modification of procedure is necessary. For example, for trees cut in 1973, if tree growth comparison is desirable at even decades, i.e., 1970, 1960, 1950, etc., the first multiple-ring count on each section from circumference must span three growth rings to reach an even decade.[7] For remainder of rings to pith, decadal counts are taken. Sequential radial increment measurements are again made from the pith outward along each established radius.

c. If desirable to compare growth of trees at specific breast height ages, e.g., at 10-year intervals, a more complicated procedure of ring count and measurement (see footnote 2, p. 3) is necessary than has been described. Decadal counts and measurements for the breast height sections must begin at the *pith*. For example, where decadal ring measurements

[7] If the 1973 growth ring is present.

are to be taken, a ring number less than 10 will likely occur as a partial decadal count next to the circumference. The number nine or less will be used to begin ring counts from the circumference on all other sections including the stump. Sequential radial increment measurements again begin at the pith and continue toward the circumference for each radius.

For this paper, the first-described multiple-ring count method--all counts begin at the circumference of each section--is used. The computer program described herein was developed accordingly. Some modification of the program is necessary to produce alternate stem analysis information describing growth at even chronological decades or at specific breast-high age intervals. It should be carefully noted that regardless of selected multiple ring count approach, all sequential growth measurement information is obtained from cumulative multiple annual ring measurements *always* taken from the pith outward toward the circumference of each section. For our computer program, that procedure is necessary to provide growth data for a normal stem profile graph of height over radius.

Unless the tree was extremely out of round or the pith obviously was excessively off geometric center, as is sometimes found in trees on very steep slopes, only one selected radius was taken for sections where longest radius differed from shortest by 10 percent or less. Otherwise, at least two radii--the longest and one about 180° to the longest--were selected. Three radii, the longest and two others about 120° each side of the longest, were taken on stump sections. For our stem analysis studies, that system always resulted in acceptable profiles. Failure to select the proper radii for annual ring counts and measurements will result in unacceptable stem profiles (fig. 15, appendix I).

Successful utilization of stem analysis field and laboratory measurements to produce stem profiles depends on reasonably accurate average radii. There are several ways to determine the average radius (pith to perimeter) of a tree stem cross-section or disk. Because of limited finances and time, selection of "representative" radii was expedient. Most of our trees were old-growth specimens, and the common occurrence of annual ring growth aberrations caused by occluded rot, scars, knots, pitch pockets, etc., usually prevented actual designation of acceptable "true average radii"[8/] from pith to perimeter on stem section disks. Instead, radii were selected that were aberration-free and representative (ocularly) of the radial growth at each section point on the stem. For easy measurement of sequential radial growth from pith to perimeter and avoidance of inaccuracies caused by missing rings (Douglass 1928), the shorter radii from any section were avoided.

When more than one radius per section was measured, sequential increment measurements of each radius were reproportioned (table 1) and a simple arithmetic average of each reproportioned radial increment was calculated and coded for

[8/] Radii derived from halving diameter tape measurements and accepting the small positive bias inherent with the diameter tape method (Matérn 1956).

keypunching (appendix I, fig. 12). Reproportioning was done by the equation:

$$RRIM = \frac{Dib/2}{TAR} (RIM)$$

Where $RRIM$ = Reproportioned sequential radial increment measurement

$Dib$ = Diameter inside bark of section as determined by diameter tape

$TAR$ = Total length of actual measured radius (representative radius)

$RIM$ = Sequential increment measurement from representative radius.

Multiple radii were averaged with a desk calculator or by a simple program on on a desk-top computer.

A more complicated method of averaging with the quadratic mean approach was suggested by Matérn (1956). According to Matérn, the quadratic mean of several random radii at each section point provides an unbiased estimate of any area, convex or not, and is applicable to closures such as those projected by tree stem cross-sections. We used available reproportioned multiple radius data, and our resulting average radii differed little from those produced by the quadratic mean approach. The differences were small (usually second and third decimal place) because all measured radii were reproportioned to the section's average radius before they were averaged (table 1).

Reproportionment of sequential radial growth measurements for sections with a single radius is automatically completed by the computer program. Therefore, such sections can be coded and keypunched as measured.

Table 1.--*Multiple radius computations for NF1, plot 75*

Section: Stump
Section height above ground: 1.5 feet
Section d.o.b.: 74.90 inches
Single bark thickness: 1.30 inches
Section ring count: 437 years

| Measured radial data | | | Reproportioned radial data | | | Average reproportioned radial data |
|---|---|---|---|---|---|---|
| Radius 1 | Radius 2 | Radius 3 | Radius 1 | Radius 2 | Radius 3 | |
| 0.78 | 0.76 | 0.83 | 0.73 | 0.80 | 0.83 | 0.79 |
| 1.82 | 1.69 | 1.80 | 1.71 | 1.79 | 1.80 | 1.77 |
| 2.97 | 2.74 | 2.90 | 2.80 | 2.90 | 2.91 | 2.87 |
| 4.41 | 3.99 | 4.19 | 4.15 | 4.22 | 4.20 | 4.19 |
| 5.96 | 5.38 | 5.65 | 5.61 | 5.70 | 5.67 | 5.66 |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| 36.69 | 32.65 | 34.45 | 34.54 | 34.56 | 34.55 | 34.55 |
| 37.15 | 33.04 | 34.88 | 34.97 | 34.98 | 34.98 | 34.98 |
| 37.62 | 33.46 | 34.32 | 35.42 | 35.42 | 35.42 | 35.42 |
| 37.91 | 33.72 | 35.59 | 35.69 | 35.69 | 35.69 | 35.69 |
| 38.40 | 34.15 | 36.05 | 36.15 | 36.15 | 36.15 | 36.15 |

Production of stem profiles from nonreproportioned measurement data for sections with a single radius, together with those having averages of reproportioned multiple radii, is completed by the computer program described and presented in appendixes II and III. Should automatic reproportionment of all radii, both single and multiple, be desired, a revision of that program is required.

## RADIAL MEASUREMENTS, SEQUENTIAL RADIAL GROWTH DATA RECORDS, AND SECTION STORAGE

Where only one radius is required, no field counts or measurements need be taken. A selected or representative radius from a transverse section cut with a small chain saw can be taken from the field for later processing in the office or laboratory (fig. 7). For sections less than 10 inches in diameter, the complete disk should be collected because of difficulty in cutting a radial section.

For both permanent ring count and sequential radial growth records where complete disk sections cannot be taken, counts and measurements on sections requiring multiple radii must be completed in the field. Heavy clear plastic overlays (fig. 8) have been used successfully for permanent ring count and growth records. Douglass (1919) used a similar technique to obtain sequential radial growth records. He used "paper rubbings" for transcribing ring-growth information from transverse radial sections.

Prior to field use, fine parallel lines spaced one-half inch apart were drawn on the transparent plastic with a sharp round point such as a push pin or shortened dissection needle. After any radius on a section was established, counts were made

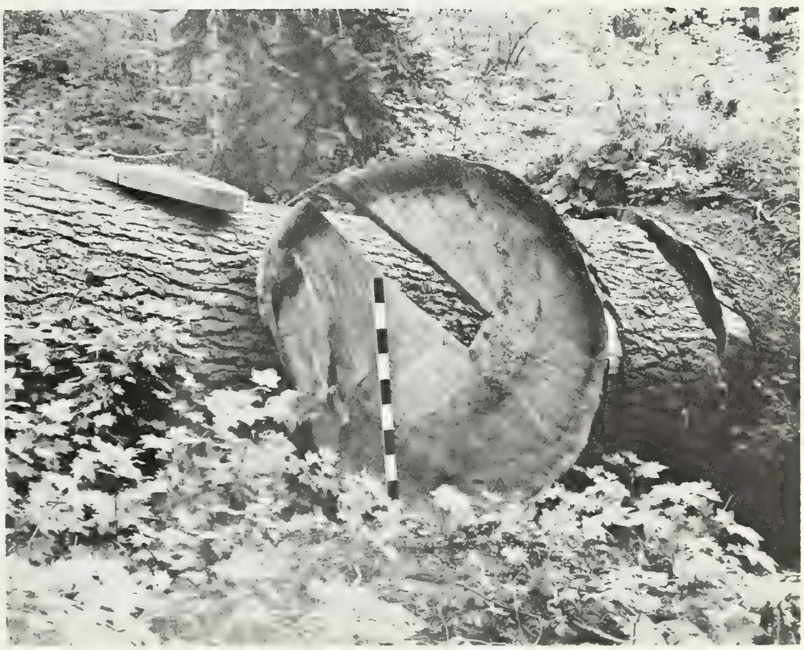

*Figure 7.--Large transverse disk from sectioned noble fir with the representative radius removed.*

*Figure 8.--Tracing radial ring pattern on plastic overlay.*

as previously described and decadal or other multiple ring marks were made on the wood with a *hard* sharp-pointed blue lead pencil. A moist surface provided darker and sharper blue pencil marks. For accuracy and uniformity, we recommend that all marks be made so that the edge of the blue pencil line coincides with the *outside* edge of the summer wood for each marked ring. Transcribing these marks to the fine parallel lines on a plastic overlay was relatively simple, again done with a sharp-pointed scriber. Where any radius was longer than a single line on the overlay, a second line, etc., with proper documentation was used for continuation. These plastic overlays were set aside for later checking and measurement and are available for other observations. Scribed marks on the clear plastic are easily seen with a dark-colored background under the plastic.

A transverse section of wood was also collected, cut with a small chain saw; it contained the best representative radius from sections (stump, b.h., etc.) from which multiple radii were transcribed to plastic. These radial transverse sections were valuable for correcting any errors later encountered.

Identification of sections is extremely important. Aluminum flashing squares (such as those used for referencing and boundary marking during surveying)--with identification scribed by ballpoint pen--were found to be the most durable method of marking wood sections. They were firmly stapled adjacent to and not covering selected radius of each section top. Each section was identified with plot number, tree species, tree number, and stem section location; e.g., "P70 NF1 127.3" means plot 70, noble fir 1, 127.3 feet above stump. "Top" of each section was always identified.

Radial transverse sections and disks for each tree were packaged with fiberglass tape. An identification tag bearing plot, tree number, species, and general location was attached to each package of radial transverse sections (fig. 9).

## Stem Analysis Laboratory and Computer Methods

Annual-ring counts and sequential radial growth measurements not completed in the field were made in the laboratory by the count plan selected. The sequential radial growth marks transcribed in the field to the plastic overlays also were measured according to the selected count plan, and the data were entered on a coding form (fig. 11, appendix I). Data on the coding forms were keypunched on standard 80-column ADP cards.

Sequential radial growth was measured with a 24-inch machinist rule graduated to the nearest hundredth of an inch except where annual rings were closely spaced. For transverse sections with rings very close together, a dendrochronograph equipped with a traveling binocular zoom microscope was used (fig. 10), and sequential radial growth was measured to the nearest hundredth of a millimeter. To correspond with ruler-measured data for our studies, metric information was converted to inches.

For easier ring counts and measurements along representative radii, the wood surface on stem section disks or radial transverse sections was smoothed with a thin-bladed, chisel-edged, hobby-type razor-knife or was sanded with an electric sander. Sanding with very fine sandpaper usually was done only when narrow growth rings (about 40 or more per inch) were encountered. Douglass (1928) favored the razor-knife method of wood surface preparation over that of

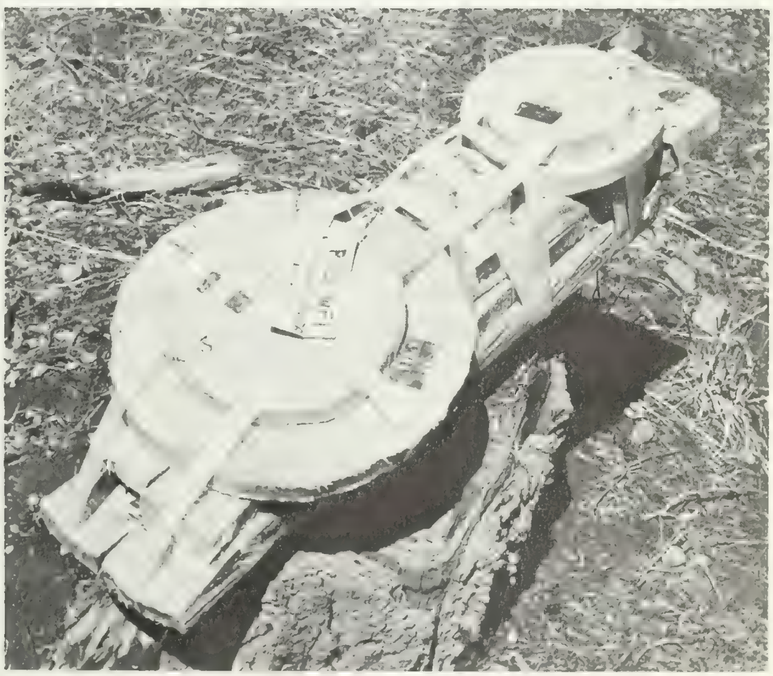

*Figure 9.--Radial transverse sections and disks packaged for laboratory examination. Tag identifies package of sections of white fir, tree number 1, from the Rogue River National Forest.*

Figure 10.--A dendrochronograph was used to measure radial growth where annual rings were closely spaced.

sanding, and our work supported that opinion. To make the annual rings more distinct, we used water for most species. For resinous wood of pines and occasionally Douglas-fir, we found that kerosene or other light oil was the best agent for enhancing the annual rings. Sophisticated wood-staining techniques were unnecessary.

Where there was concern for radial shrinkage in the collected radial sections and transverse disks, the current year's or "green" radii were placed on the plastic overlays in the field. Two marks--pith center and section perimeter edge--were transcribed to these plastic overlays. Before laboratory ring counts and sequential radial growth measurements were taken, green dimensions were restored by soaking the collected specimens in water (Herman and DeMars 1970) for at least 24 hours, then draining them overnight. Radii of green sections that were correctly marked on the plastic always corresponded closely to those of the water-restored sections. Ring intervals for these field-selected representative radii then were marked off and measured according to the selected count plan.

## COMPUTER PROGRAM FOR STEM ANALYSIS DATA

At least two previous programs using stem analysis data for computing and graphing tree growth are in existence (Brace and Magar 1968, Pluth and Cameron 1971). Both of these automated methods machine-plot derived tree growth parameters. Neither program provides a standard height-radius stem profile as provided in this paper. Both programs provide volume and basal area computations that could be adapted for use with our program.

Preparation for computer production of stem analysis data requires coding of the field and the laboratory data from stem disks and scribed plastic overlays. Figure 12, appendix I, is a stem analysis data code completed for "NF1, plot 75." From data sheets such as these, 80-column ADP cards were keypunched and verified. A computer was programed to produce for each tree: (1) a stem analysis graph (fig. 13, appendix I) using reproportioned radial data and straight-line interpolated heights, (2) listing of reproportioned radial data corresponding to the stem analysis profile, (3) a set of ADP cards punched to contain the reproportioned data, (4) a height-age listing by the selected ring-count interval using straight-line interpolation, (5) a height-age graph of the original tree data, and (6) a set of ADP cards punched to contain the selected ring count interval height-age data.

Any or all of the previous items can be selected as output for an individual tree on a single run. These options are explained in appendix II, card type I.

## EDITING STEM ANALYSIS DATA USING THE COMPUTER PROGRAM

In actual practice, usually only the stem profile was plotted first to discover if any errors existed in the raw data. Such errors (figs. 14 and 15, appendix I) were readily determined and corrections were made to insure that the changes were correct. Following the production of an acceptable stem profile graph, the remaining computer program options were selected for completion. Data editing using the stem profile graph should be done cautiously because not all apparently eccentric profile graph lines are measurement errors. Some line aberrations can be caused by growth problems such as old stem breaks, forks, etc.

* * * *

A copy of the stem analysis program listing is in appendix III. Further information about the program may be obtained from the Pacific Northwest Forest and Range Experiment Station, P. O. Box 3141, Portland, Oregon 97208.

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# Appendix I

Table 2.--*Noble fir and associated species felled and sectioned during stem analysis studies*

| Common name | Scientific name[1] | Species ADP code |
|---|---|---|
| noble fir | *Abies procera* Rehd. | 022 |
| Douglas-fir[2] | *Pseudotsuga menziesii* (Mirb.) Franco | 202 |
| Pacific silver fir | *Abies amabilis* (Dougl.) Forbes | 011 |
| western hemlock | *Tsuga heterophylla* (Raf.) Sarg. | 263 |
| mountain hemlock | *Tsuga mertensiana* (Bong.) Carr. | 264 |
| western white pine | *Pinus monticola* Dougl. | 119 |
| grand fir[2] | *Abies grandis* (Dougl.) Lindl. | [3] 015 |
| western redcedar | *Thuja plicata* Donn. | 254 |
| subalpine fir | *Abies lasiocarpa* (Hook.) Nutt. | 019 |
| western larch | *Larix occidentalis* Nutt. | 073 |
| lodgepole pine | *Pinus contorta* Dougl. | 108 |
| Engelmann spruce | *Picea engelmannii* Parry | 093 |
| Shasta red fir[2] | *Abies magnifica* var. *shastensis* Lemm. | 021 |
| ponderosa pine[2] | *Pinus ponderosa* Laws. | 122 |

1/ Scientific names follow Elbert L. Little, Jr., Check list of native and naturalized trees of the United States (including Alaska). U.S. Department of Agriculture, Agriculture Handbook 41, 472 p., 1953.

2/ Species associated with Shasta red fir felled and sectioned south of the known normal range of noble fir. Douglas-fir and grand fir (white fir) were sampled in both the noble fir range and Shasta red fir range.

3/ Grand fir and white fir considered as single species for this phase of study--both coded "015."

STEM ANALYSIS DATA    Plot no.______    Tree no.______    Date felled______    Initials______

Study no.______    Plot name______    Species______    Date measured______    Sheet____of____

Columns 1–80:

- Plot Number
- Tree Number
- Species Code
- Diameter Breast Height
- Age at Breast Height
- Card Number
- Number of Sections Including Tip
- Annual Ring Increment
- St.Ht. Cumulative Height Above Stump
- Section Diameters Outside Bark
- Bark Thickness
- Age of Section
- Cumulative Annual Ring Measurement From Pith @ Stump
- Cumulative Annual Ring Measurement From Pith @ B.H.
- Cumulative Annual Ring Measurement From Pith
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.
- Etc.

*Figure 11.--Stem analysis data code sheet.*

STEM ANALYSIS DATA Plot no. 75 Tree no. 1 Date felled 8/11/68 Initials [illegible]
Study no. W61, W63 Plot name Yellowjacket Creek Species Noble Fir Date measured 8/12/68 Sheet 1 of 2

| 1-2 | 3 | 4-6 | 8-10 | 12-14 | 16-17 | 18 | 19 | 20 | 21-24 | 25-28 | 29-32 | 33-36 | 37-40 | 41-44 | 45-48 | 49-52 | 53-56 | 57-60 | 61-64 | 65-68 | 69-72 | 73-76 | 77-80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75 | 1 | 022 | 658 | 432 | 1 | 2 | 1 | 1 | 15 | 30 | 214 | 394 | 573 | 754 | 934 | 1114 | 1292 | 1472 | 1653 | 1844 | 2064 | 2287 | 2417 |
| | | | | | 2 | | | | 2494 | 2583 | 2640 | 2669 | 2691 | 2711 | | | | | | | | | |
| | | | | | 3 | | | | 7490 | 6580 | 5410 | 5240 | 5050 | 4860 | 4750 | 4660 | 4310 | 4298 | 3880 | 3314 | 2510 | 1765 | 1214 |
| | | | | | 4 | | | | 912 | 590 | 335 | 214 | 137 | 0 | | | | | | | | | |
| | | | | | 5 | | | | 130 | 157 | 118 | 118 | 95 | 105 | 115 | 150 | 162 | 179 | 140 | 162 | 137 | 128 | 84 |
| | | | | | 6 | | | | 66 | 42 | 21 | 14 | 10 | 0 | | | | | | | | | |
| | | | | | 7 | | | | 437 | 432 | 415 | 399 | 381 | 374 | 366 | 354 | 340 | 324 | 301 | 273 | 229 | 169 | 127 |
| | | | | | 8 | | | | 93 | 64 | 38 | 23 | 16 | 0 | | | | | | | | | |
| | | | | | 9 | | | | 79 | 23 | | | | | | | | | | | | | |
| | | | | | 10 | | | | 177 | 144 | | | | | | | | | | | | | |
| | | | | | 11 | | | | 287 | 230 | 44 | | | | | | | | | | | | |
| | | | | | 12 | | | | 419 | 314 | 188 | | | | | | | | | | | | |
| | | | | | 13 | | | | 566 | 433 | 362 | 137 | | | | | | | | | | | |
| | | | | | 14 | | | | 698 | 530 | 528 | 285 | 15 | | | | | | | | | | |
| | | | | | 15 | | | | 831 | 642 | 619 | 446 | 245 | 70 | | | | | | | | | |
| | | | | | 16 | | | | 990 | 756 | 742 | 613 | 446 | 318 | 104 | | | | | | | | |
| | | | | | 17 | | | | 1125 | 844 | 830 | 728 | 591 | 506 | 303 | 65 | | | | | | | |
| | | | | | 18 | | | | 1246 | 924 | 910 | 829 | 709 | 646 | 459 | 236 | | | | | | | |
| | | | | | 19 | | | | 1294 | 1009 | 995 | 920 | 822 | 760 | 582 | 361 | 165 | | | | | | |
| | | | | | 20 | | | | 1472 | 1087 | 1074 | 1001 | 928 | 865 | 703 | 480 | 322 | 60 | | | | | |
| | | | | | 21 | | | | 1555 | 1163 | 1149 | 1073 | 1015 | 949 | 799 | 591 | 456 | 199 | | | | | |
| | | | | | 22 | | | | 1660 | 1214 | 1200 | 1134 | 1093 | 1028 | 874 | 699 | 580 | 307 | 16 | | | | |
| | | | | | 23 | | | | 1760 | 1284 | 1270 | 1211 | 1174 | 1105 | 954 | 790 | 700 | 410 | 160 | | | | |
| | | | | | 24 | | | | 1851 | 1366 | 1351 | 1295 | 1263 | 1176 | 1026 | 875 | 806 | 516 | 280 | | | | |
| | | | | | 25 | | | | 1930 | 1457 | 1420 | 1371 | 1341 | 1240 | 1100 | 956 | 899 | 631 | 385 | 29 | | | |
| | | | | | 26 | | | | 2040 | 1527 | 1466 | 1421 | 1406 | 1304 | 1164 | 1015 | 970 | 705 | 472 | 155 | | | |
| | | | | | 27 | | | | 2169 | 1621 | 1517 | 1479 | 1467 | 1380 | 1243 | 1089 | 1041 | 790 | 561 | 251 | | | |
| | | | | | 28 | | | | 2315 | 1698 | 1586 | 1542 | 1521 | 1444 | 1310 | 1163 | 1101 | 871 | 653 | 353 | | | |
| | | | | | 29 | | | | 2425 | 1779 | 1658 | 1602 | 1587 | 1516 | 1380 | 1240 | 1165 | 950 | 740 | 455 | | | |
| | | | | | 30 | | | | 2512 | 1833 | 1695 | 1637 | 1629 | 1582 | 1454 | 1316 | 1211 | 1011 | 795 | 526 | 111 | | |
| | | | | | 31 | | | | 2578 | 1901 | 1737 | 1700 | 1667 | 1629 | 1500 | 1368 | 1255 | 1066 | 859 | 597 | 217 | | |
| | | | | | 32 | | | | 2652 | 1998 | 1810 | 1749 | 1724 | 1680 | 1555 | 1420 | 1308 | 1119 | 916 | 660 | 299 | | |
| | | | | | 33 | | | | 2724 | 2086 | 1879 | 1806 | 1780 | 1737 | 1616 | 1480 | 1350 | 1170 | 967 | 709 | 353 | | |
| | | | | | 34 | | | | 2768 | 2161 | 1933 | 1866 | 1825 | 1783 | 1662 | 1537 | 1383 | 1225 | 1013 | 749 | 418 | | |
| | | | | | 35 | | | | 2803 | 2208 | 1975 | 1909 | 1859 | 1821 | 1700 | 1574 | 1421 | 1274 | 1060 | 785 | 471 | | |

BPA 192 Rev. [illegible]

Figure 12.--Completed stem analysis data code sheet for noble fir 1, plot 75.

STEM ANALYSIS DATA — Study no. W61, W'63 — Plot no. 75 — Plot name Yellowjacket Creek — Tree no. 1 — Species Noble Fir — Date felled 8/11/68 — Date measured 8/12/68 — Initials [illegible] — Sheet 2 of 2

| 1–3 | 4–7 | 8–11 | 12–15 | 16–17 | 18–19 | 20 | 21–24 | 25–28 | 29–32 | 33–36 | 37–40 | 41–44 | 45–48 | 49–52 | 53–56 | 57–60 | 61–64 | 65–68 | 69–72 | 73–76 | 77–80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75 | 1022 | 658 | 432 | 36 | 21 | 1 | 2867 | 2255 | 2010 | 1940 | 1894 | 1852 | 1741 | 1617 | 1454 | 1320 | 1103 | 826 | 525 | 95 | |
| | | | | 37 | | | 2935 | 2313 | 2055 | 1987 | 1931 | 1887 | 1778 | 1663 | 1489 | 1375 | 1149 | 870 | 570 | 192 | |
| | | | | 38 | | | 2994 | 2378 | 2096 | 2026 | 1965 | 1920 | 1809 | 1693 | 1516 | 1420 | 1187 | 904 | 610 | 251 | |
| | | | | 39 | | | 3052 | 2434 | 2139 | 2066 | 2007 | 1957 | 1844 | 1729 | 1548 | 1465 | 1238 | 932 | 652 | 326 | |
| | | | | 40 | | | 3146 | 2502 | 2184 | 2111 | 2048 | 1996 | 1888 | 1761 | 1579 | 1506 | 1261 | 966 | 703 | 380 | 65 |
| | | | | 41 | | | 3186 | 2545 | 2220 | 2146 | 2089 | 2036 | 1930 | 1800 | 1610 | 1546 | 1296 | 1004 | 751 | 433 | 150 |
| | | | | 42 | | | 3225 | 2584 | 2245 | 2171 | 2117 | 2079 | 1977 | 1839 | 1649 | 1594 | 1342 | 1040 | 790 | 475 | 198 |
| | | | | 43 | | | 3266 | 2642 | 2275 | 2197 | 2145 | 2121 | 2007 | 1878 | 1679 | 1625 | 1366 | 1060 | 823 | 515 | 243 |
| | | | | 44 | | | 30 | | | | | | | | | | | | | | |
| | | | | 45 | | | 3311 | 2710 | 2303 | 2225 | 2172 | 2158 | 2040 | 1915 | 1707 | 1662 | 1409 | 1100 | 865 | 558 | 288 |
| | | | | 46 | | | 128 | | | | | | | | | | | | | | |
| | | | | 47 | | | 3343 | 2771 | 2329 | 2250 | 2199 | 2195 | 2080 | 1952 | 1740 | 1701 | 1448 | 1131 | 903 | 591 | 320 |
| | | | | 48 | | | 194 | | | | | | | | | | | | | | |
| | | | | 49 | | | 3378 | 2834 | 2357 | 2278 | 2227 | 2232 | 2123 | 1985 | 1766 | 1743 | 1479 | 1161 | 943 | 629 | 360 |
| | | | | 50 | | | 245 | 32 | | | | | | | | | | | | | |
| | | | | 51 | | | 3418 | 2889 | 2412 | 2333 | 2272 | 2277 | 2169 | 2020 | 1793 | 1799 | 1507 | 1195 | 989 | 663 | 394 |
| | | | | 52 | | | 293 | 100 | | | | | | | | | | | | | |
| | | | | 53 | | | 3455 | 2935 | 2442 | 2362 | 2303 | 2311 | 2206 | 2051 | 1820 | 1837 | 1532 | 1218 | 1029 | 695 | 420 |
| | | | | 54 | | | 227 | 162 | | | | | | | | | | | | | |
| | | | | 55 | | | 3498 | 2988 | 2486 | 2403 | 2342 | 2359 | 2239 | 2082 | 1844 | 1880 | 1560 | 1243 | 1070 | 724 | 450 |
| | | | | 56 | | | 357 | 202 | 66 | | | | | | | | | | | | |
| | | | | 57 | | | 3542 | 3037 | 2520 | 2436 | 2379 | 2399 | 2270 | 2121 | 1870 | 1910 | 1586 | 1270 | 1110 | 751 | 470 |
| | | | | 58 | | | 379 | 227 | 112 | 29 | | | | | | | | | | | |
| | | | | 59 | | | 3569 | 3091 | 2560 | 2475 | 2409 | 2444 | 2307 | 2152 | 1904 | 1936 | 1613 | 1299 | 1142 | 780 | 490 |
| | | | | 60 | | | 395 | 240 | 130 | 74 | 29 | | | | | | | | | | |
| | | | | 61 | | | 3615 | 3133 | 2587 | 2502 | 2430 | 2478 | 2341 | 2173 | 1945 | 1953 | 1635 | 1320 | 1168 | 800 | 503 |
| | | | | 62 | | | 405 | 250 | 140 | 95 | 55 | | | | | | | | | | |

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*Figure 12 (Cont'd.)--Completed stem analysis data code sheet for noble fir 1, plot 75.*

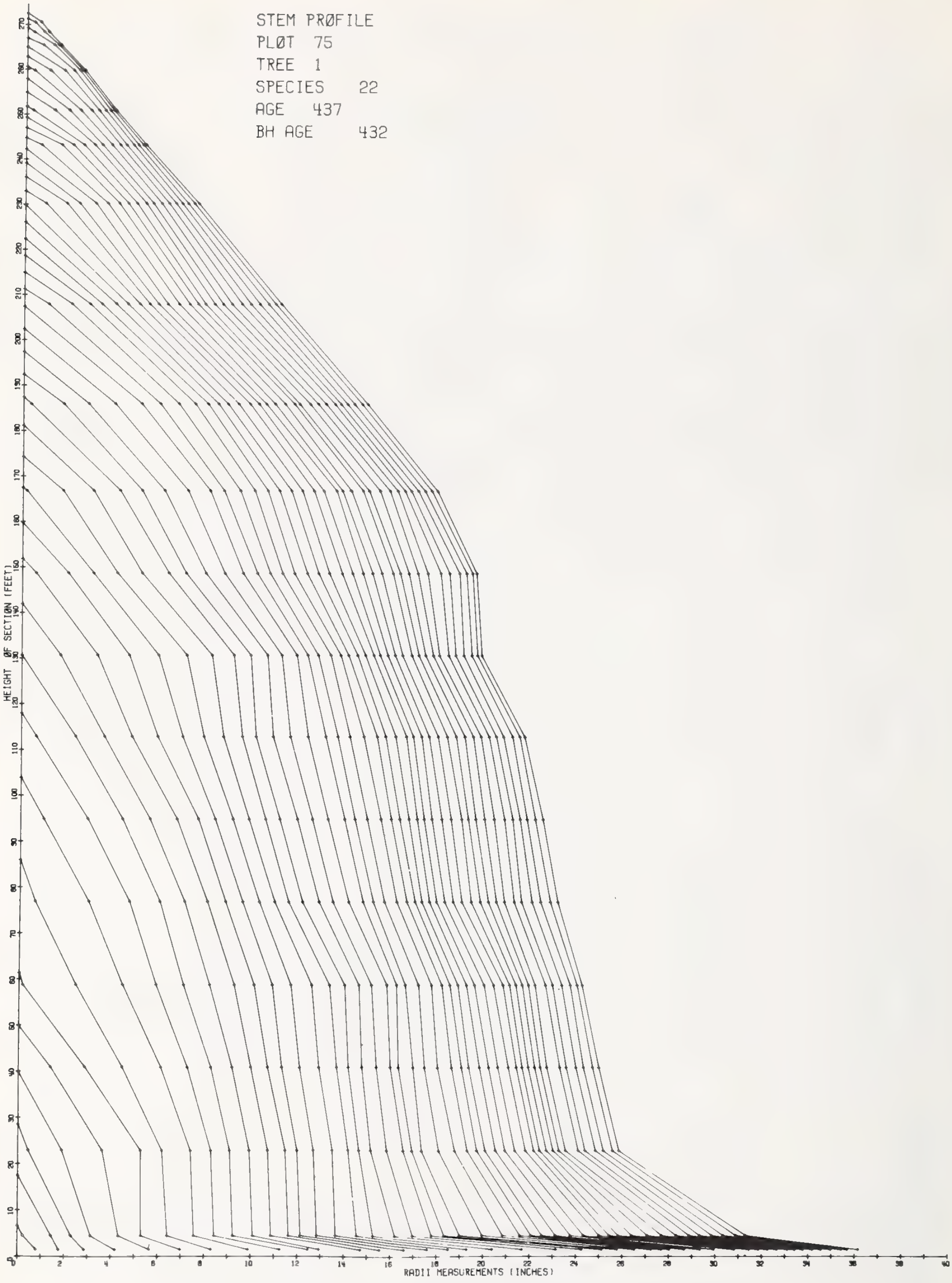


*Figure 13.--Computer produced stem profile chart for noble fir 1, plot 75.*

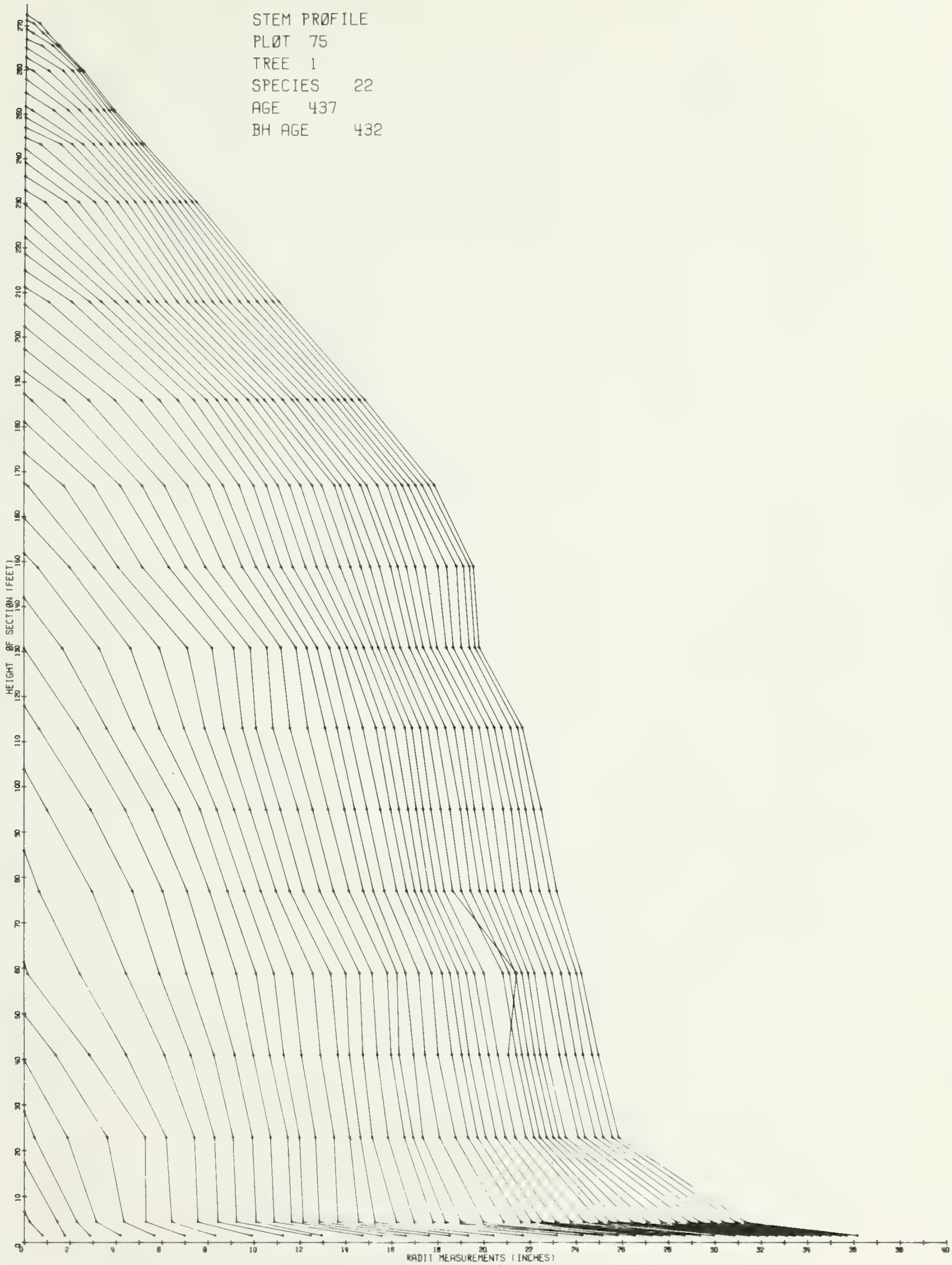


*Figure 14.--Computer produced stem profile graph showing error in data.*

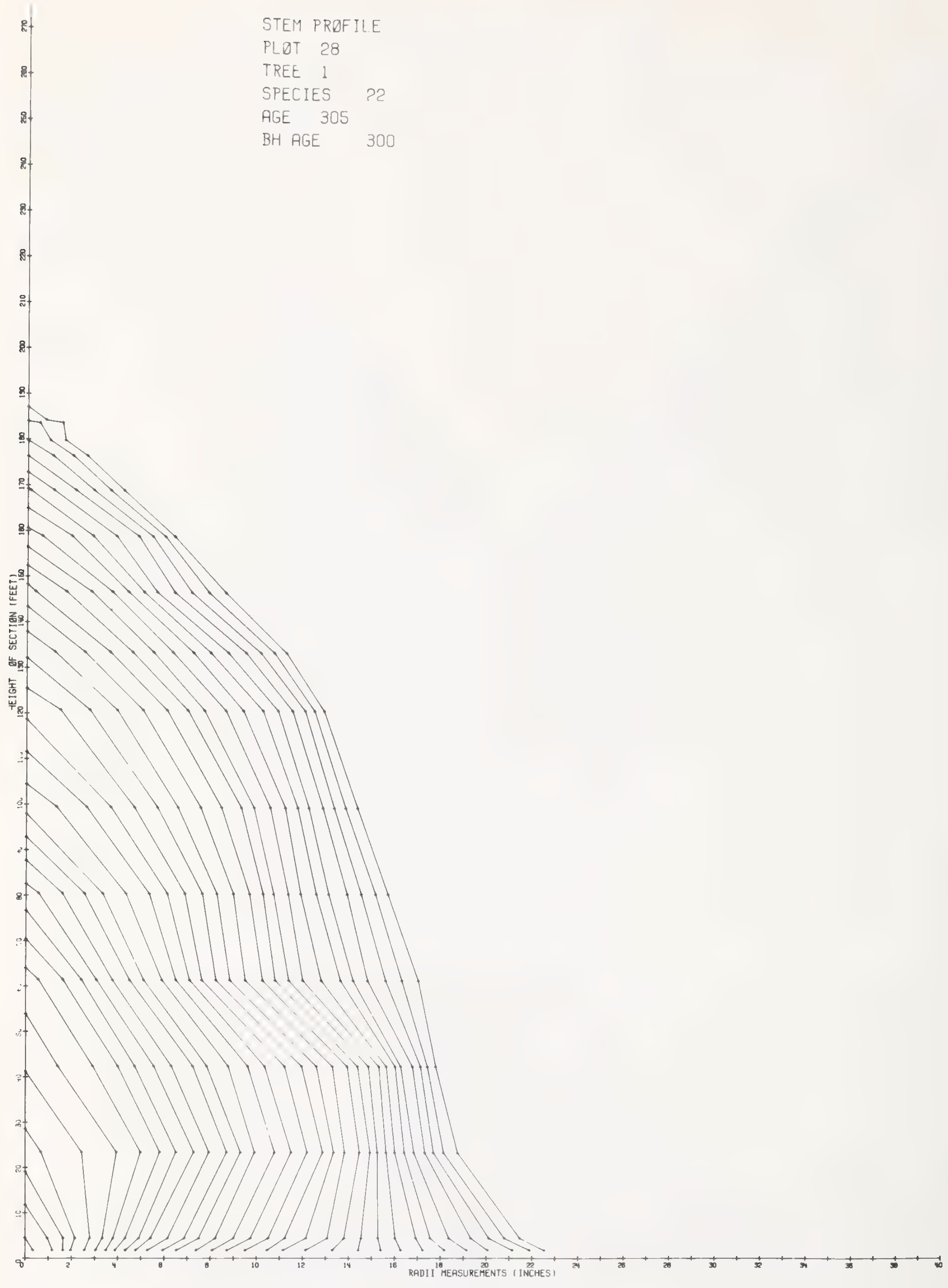


*Figure 15.--Computer produced stem profile showing results of inadequate data measurements at lower stem section points.*

# Appendix II

## Card Input Formats

With the exception of the "00" card, the program[1] data input cards can be punched directly from the stem analysis data code sheets (figs. 11 and 12 of appendix I). Descriptive plot and miscellaneous tree information to be punched on the "00" card comes from various places in the original field notes. Transcription of that information into the following format is mandatory.

Card Type I--"00" Card

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-3 | XXX | Plot number | |
| 4 | X | Tree number | |
| 5-7 | XXX | Species code | Table 2, appendix I |
| 8-11 | XXX.X | D.b.h. (o.b.) | Inches |
| 12-15 | XXXX | Breast height ring count | |
| 16-17 | XX | Card number | Always "00" |
| 18-19 | XX | Number of sections taken for the tree | (Including tip, limit--30) |
| 20 | X | Ring count measurement interval (years) | 1 = 10 yr<br>5 = 5 yr<br>3 = 1 yr |
| 21-22 | XX | Year cut | |
| 23-24 | XX | Crown class | Dominant and tallest on plot--11<br>Dominant--1<br>Codominant--2<br>Intermediate--3<br>Suppressed--4 |
| 25-28 | XXX.X | Height to first live limb (feet) | Above average ground level |
| 29-32 | XXX.X | Height to live crown (feet) | Above average ground level |
| 33-36 | XXX.X | Clear length (feet) | Above average ground level |
| 37-40 | XXX.X | Crown length (feet) | Above average ground level |

[1] Regardless of tree size or age, program is adaptable to data from 30 section points where the 30th section point is the tip having a diameter of "0" and a single bark thickness of "0." Also, program is limited to 80 incremental measurement intervals. Expressed in terms of stump age, program will accommodate an 80-year-old tree at 1-ring measurement intervals, a 400-year-old tree at 5-ring measurement intervals, or an 800-year-old tree at 10-ring measurement intervals.

Card Type I--"00" Card, continued

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 41-45 | XXXXX | Elevation (feet) | |
| 46 | X | Blank | |
| 47 | X | Aspect | Aspect codes<br>Level - 0<br>North, northeast 1,2<br>East, southeast 3,4<br>South, southwest 5,6<br>West, northwest 7,8 |
| 48-50 | XXX | Slope (percent) | |
| 51-56 | XXXXX.X | Latitude north | Cols. 51-53 degrees<br>Cols. 54-56 min |
| 57-62 | XXXXX.X | Longitude west | Cols. 57-59 degrees<br>Cols. 60-62 min |
| 63-65 | XXX | Preliminary noble fir site index | From PNW-119 Res. Note 1970[2/] |
| 66-69 | XXX.X | Total tree height (feet) | |
| 70-74 | XXXXX | Blank | |
| 75 | X | Card output of reproportioned data | To suppress output, punch a "1"; otherwise leave blank. |
| 76 | X | Printed output of reproportioned data | To suppress output, punch a "1"; otherwise leave blank. |
| 77 | X | Stem profile | To suppress output, punch a "1"; otherwise leave blank. |
| 78 | X | Card output of height-age data by the selected ring count interval | To suppress output, punch a "1"; otherwise leave blank. |
| 79 | X | Printed output of height-age data by the selected ring count interval | To suppress output, punch a "1"; otherwise leave blank. |
| 80 | X | Height-age plot of original tree data | To suppress output, punch a "1"; otherwise leave blank. |

[2/] Donald J. DeMars, Francis R. Herman, and John F. Bell. Preliminary site index curves for noble fir from stem analysis data. USDA Forest Service Research Note PNW-119, 9 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 1970.

Card Type II--Section Height Card

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-3 | XXX | Plot number | |
| 4 | X | Tree number | |
| 5-7 | XXX | Species | See ADP code table 2, appendix I |
| 8-11 | XXX.X | D.b.h. (o.b.) | Inches |
| 12-15 | XXXX | Breast height age | Years |
| 16-17 | XX | Card number | Card position in tree deck |
| 18-19 | XX | Number of sections | (Including tip) limit: 30 or less |
| 20 | X | Ring count measurement interval | 1 = 10-yr interval<br>5 = 5-yr interval<br>3 = 1-yr interval |
| 21-24 | XXX.X | Stump height (ft) | Section 1 |
| 25-28 | XXX.X | Height above the stump of breast height section | Section 2 |
| 29-32 | XXX.X | Height above the stump of section 3 | Section 3 |
| 33-36 | XXX.X | Height above the stump of section 4 | Section 4 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 77-80 | XXX.X | Height above the stump of section 15 | Section 15 |

Up to 15 section heights can be punched on one computer card, and the program can process up to 30 section heights for any one tree. The additional section heights are punched on a continuation card (same format as above) with section 16 height data entered in columns 21-24. It should be noted that the tip height measurement is considered one section. Columns 1 to 20 of the continuation card will be a duplicate of the previous card except for columns 16 and 17 which will contain the card's position number in the tree deck.

Card Type III--Section Diameter (Outside Bark) Card

For every section height, a corresponding diameter outside bark is needed (tip height diameter equals zero).

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-15 | (Same as section height card) | | |
| 16-17 | XX | Card number | Card position in tree deck |
| 18-20 | (Same as section height card) | | |
| 21-24 | XX.XX | D.o.b. of stump section | Section 1 |
| 25-28 | XX.XX | D.o.b. of breast height section | Section 2 |
| 29-32 | XX.XX | D.o.b. of section 3 | Section 3 |
| 33-36 | XX.XX | D.o.b. of section 4 | Section 4 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 77-80 | XX.XX | D.o.b. of section 15 | Section 15 |

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the diameter outside bark of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

Card Type IV--Single Bark Thickness Card

For every section height a corresponding single bark-thickness is needed (tip height bark thickness equals zero).

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-15 | (Same as section height card) | | |
| 16-17 | XX | Card number | Card position in tree deck |
| 18-20 | (Same as section height card) | | |
| 21-24 | XX.XX | Single bark thickness of stump section | Section 1 |
| 25-28 | XX.XX | Single bark thickness of breast height section | Section 2 |
| 29-32 | XX.XX | Single bark thickness of section 3 | Section 3 |
| 33-36 | XX.XX | Single bark thickness of section 4 | Section 4 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 77-80 | XX.XX | Single bark thickness of section 15 | Section 15 |

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the single bark thickness of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

## Card Type V--Section Ring Count

For every section height a corresponding section ring count is needed (tip height ring count equals zero).

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-15 | (Same as section height card) | | |
| 16-17 | XX | Card number | Card position in tree deck |
| 18-20 | (Same as section height card) | | |
| 21-24 | XXXX | Ring count of stump section | Section 1 |
| 25-28 | XXXX | Ring count of breast height section | Section 2 |
| 29-32 | XXXX | Ring count of section 3 | Section 3 |
| 33-36 | XXXX | Ring count of section 4 | Section 4 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 77-80 | XXXX | Ring count of section 15 | Section 15 |

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the ring count of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

Card Type VI--Sequential Radial Increment Measurements Card

The remainder of the tree data deck consists of card type VI. The format for this card is:

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-15 | (Same as section height card) | | |
| 16-17 | XX | Card number | Card position in tree deck |
| 18-20 | (Same as section height card) | | |
| 21-24 | XX.XX | Radial increment measurements for stump section | Section 1 |
| 25-28 | XX.XX | Radial increment measurements for stump section | Section 2 |
| 29-32 | XX.XX | Radial increment measurements for stump section 3 | Section 3 |
| 33-36 | XX.XX | Radial increment measurements for stump section 4 | Section 4 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 77-80 | XX.XX | Radial increment measurements for stump section 15 | Section 15 |

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the radial increment measurement of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card, except columns 16 and 17 will contain the card's position number in the tree deck.

## Coding Format Layout Determination

Before card type VI can be punched, the radial increment data must be recorded on stem analysis data forms in a manner similar to that shown in figure 12 of appendix I, and as follows:

1. Calculate the total number of lines needed to record the stump radial measurements.

   $$\text{Number of lines} = \frac{\text{Ring count of stump section (years)}}{\text{Ring count interval (years)}}$$

   If the answer is not a whole number, round the answer up to the next whole number. Figure 12 example: 437/10 = 43.7. Next whole number; in this instance, 44 lines. Any decimal except .0 requires such rounding.
2. Calculate the number of lines needed to record the radial measurements for the 16th section (if there is a 16th section). If the 16th section is the tip, then one line is required to record the needed zero. Figure 12 example: 93/10 = 9.3. Round up to 10 lines.
3. Calculate the total number of lines that will be needed for the tree. Total number of lines = number of lines used for heights, diameter, age, and bark + number of lines needed for stump section + number of lines needed for 16th section. Figure 12 example: 8 + 44 + 10 = 62 lines.
4. In columns 16 and 17 of the stem analysis data coding forms, number the lines consecutively up to the total number of lines calculated in item 3. Use additional forms if needed.
5. Calculate the line number where the first radial measurement of section 16 will be recorded.

   Line number = Total number of lines - [ (number of lines needed for section 16) - 1] * 2 (asterisks used in computer coding format layout determination formulas mean "*multiplied by.*" )

   Figure 12 example: 62 - (10-1) * 2 = 44
6. Starting on the line calculated in item 5 and skipping every other line, record the radial increment measurements for the 16th section in columns 21-24 of the data forms. Last entry for section 16 should fall on line 62.
7. For all sections above the 16th section, calculate the line number where each section's first radial measurement will be recorded on the data forms. This calculation is as follows:

   Line number for section "i" = Total number of lines - [(number of lines needed for section "i") -1] * 2

   Where:

   The number of lines needed for section "i" is calculated by the formula in item 1.

   Figure 12 example for section 17: Line number = 62 - [(7-1) * 2] = 50
8. Starting on the line number calculated for section "i" in item 7, record section "i's" radial increment measurement data on every other line in the appropriate columns of the data forms.

9. Radial increment measurements for the stump section will begin on the line immediately following the last section ring count line (card type V) and will be recorded on consecutive lines until the first measurement of section 16 is encountered in columns 21-24 of the data form. When this occurs, subsequent radial measurements will be recorded on every other line until completion of the stump measurements.
10. For any "k" section 2 through 15, the beginning line number can be calculated by by the following formula:
Line number = Total number of lines - (Lines required for 16th section) - (Lines required to record section "k") + 1: Where the number of lines needed for section "k" is calculated by the formula in item 1.
Figure 12 example -- Section 2: Line number = 62 - 10 - 44 + 1 = 9
-- Section 3: Line number = 62 - 10 - 42 + 1 = 11
11. Record sections 2 through 15 beginning on the proper line number (as calculated in item 10) for the section being measured. *Remember* that all lines that have section 16 recorded on them will be skipped when recording sections 2 through 15. Because the above instructions are involved, we recommend that figure 12 of appendix I be studied for a full understanding of the proper format for the program input cards.

## Program Output

Program output consists of punched card output as well as printed output. An example of printed output is shown in figures 16 and 17 of this appendix.

Two card decks are produced for each tree. One deck contains the rescaled sequential radial increment data and the other contains the age-height-site index information. The rescaled sequential radial increment deck has a format identical to the input card format.

The format for the age-height-site index output card is:

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 1-2 | XX | Study | |
| 3-6 | XXXX | Project | |
| 7-10 | XXXX | Species code | See table 2, appendix I |
| 11-13 | XXX | Plot number | |
| 14-16 | XXX | Tree number | |
| 17-18 | XX | Composite tree (normally 1) | 1 = single tree, 2 or greater = composite tree used for averaging |
| 19-22 | XXXX | Stump age | |
| 23-26 | XXXX | Total breast height age | |
| 27-30 | XXXX | Site index at b. h., age 100 | Blank if tree is less than 100 years at b. h. |

| Card columns | Implied decimal designation | Identification | Special notes |
|---|---|---|---|
| 31-34 | XXXX | Height above breast height | Interpolated values for each decadal ring count interval multiple |
| 35-38 | XXXX | Cumulative breast height age by successive decades | Decadal multiples of ring count measurement interval |
| 39-46 | XXXXXXXX | Blank | |
| 47-49 | XXX | Number of cards in this tree's site index deck | |
| 50-80 | | Blank | |

| ST | PRO | SPE | PLOT | TREE | C T | STUMP AGE | B.H. AGE | SITE -4.5 | HEIGHT -4.5 | CUM B.H. AGE | CARDS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 10.82 | 10 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 21.77 | 20 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 33.02 | 30 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 43.36 | 40 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 53.31 | 50 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 76.90 | 60 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 96.40 | 70 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 110.94 | 80 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 123.66 | 90 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 135.20 | 100 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 145.77 | 110 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 153.64 | 120 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 161.51 | 130 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 168.44 | 140 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 175.26 | 150 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 181.90 | 160 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 186.90 | 170 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 191.90 | 180 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 196.90 | 190 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 201.90 | 200 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 206.00 | 210 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 209.72 | 220 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 213.43 | 230 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 217.15 | 240 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 220.87 | 250 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 224.58 | 260 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 227.87 | 270 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 230.36 | 280 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 234.06 | 290 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 237.15 | 300 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 239.83 | 310 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 242.10 | 320 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 244.36 | 330 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 246.71 | 340 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 249.78 | 350 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 252.84 | 360 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 255.74 | 370 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 257.93 | 380 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 260.12 | 390 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 262.16 | 400 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 264.21 | 410 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 266.60 | 420 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 267.85 | 430 | 44 |
| 1 | | 22 | 75 | 1 | 1 | 437 | 432 | 135.20 | 268.10 | 432 | 44 |

*Figure 16.--Height-age-site index written output.*

TREE AND PLOT INFORMATION

DBH= 65.8 , B.H. AGE= 432 CROWN CLASS= 11 HEIGHT TO FIRST LIVE LIMB=123.0 HEIGHT TO LIVE CROWN=123.0

PRELIMINARY NOBLE FIR SITE INDEX=141 CLEAR LENGTH=123.0 CROWN LENGTH=149.6 TOTAL TREE HEIGHT= 272.6

ELEVATION= 2903 ASPECT= 4 SLOPE= 10% LATITUDE NORTH= 46 DEG 17.0 MIN LONGITUDE WEST= 121 DEG 50.6 MIN

SPECIES = 22
PLOT NO. 75 TREE NO. 1

| ST.HT ** | DISTANCE FROM STUMP | | | | | | | | | | DISTANCE FROM STUMP | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 3.0 | 21.4 | 39.4 | 57.3 | 75.4 | 93.4 | 111.4 | 129.2 | 147.2 | 165.3 | 184.4 | 206.4 | 229.7 | 241.7 | 249.4 | 258.3 | 264.0 | 266.9 | 269.1 | 271.1 |
| DIA OB | 74.9 | 65.8 | 54.1 | 52.4 | 50.5 | 48.6 | 47.5 | 46.6 | 43.1 | 43.0 | 38.8 | 33.1 | 25.1 | 17.6 | 12.1 | 9.1 | 5.9 | 3.3 | 2.1 | 1.4 | |
| BARK | 1.30 | 1.57 | 1.18 | 1.18 | .95 | 1.05 | 1.15 | 1.50 | 1.62 | 1.79 | 1.40 | 1.62 | 1.37 | 1.28 | .84 | .66 | .42 | .21 | .14 | .10 | |
| AGE | 437 | 432 | 415 | 399 | 381 | 374 | 366 | 354 | 340 | 324 | 301 | 273 | 229 | 169 | 127 | 93 | 64 | 38 | 23 | 16 | |
| 1538 | .79 | .23 | | | | | | | | | | | | | | | | | | | |
| 1548 | 1.77 | 1.44 | | | | | | | | | | | | | | | | | | | |
| 1558 | 2.87 | 2.30 | .44 | | | | | | | | | | | | | | | | | | |
| 1568 | 4.19 | 3.14 | 1.88 | | | | | | | | | | | | | | | | | | |
| 1578 | 5.66 | 4.33 | 3.62 | 1.37 | | | | | | | | | | | | | | | | | |
| 1588 | 6.98 | 5.30 | 5.28 | 2.85 | .15 | | | | | | | | | | | | | | | | |
| 1598 | 8.31 | 6.42 | 6.19 | 4.46 | 2.45 | .66 | | | | | | | | | | | | | | | |
| 1608 | 9.90 | 7.56 | 7.42 | 6.13 | 4.46 | 2.98 | 1.00 | | | | | | | | | | | | | | |
| 1618 | 11.25 | 8.44 | 8.30 | 7.28 | 5.91 | 4.75 | 2.93 | .65 | | | | | | | | | | | | | |
| 1628 | 12.46 | 9.24 | 9.10 | 8.29 | 7.09 | 6.06 | 4.43 | 2.37 | | | | | | | | | | | | | |
| 1638 | 12.94 | 10.09 | 9.95 | 9.20 | 8.22 | 7.13 | 5.62 | 3.62 | 1.69 | | | | | | | | | | | | |
| 1648 | 14.72 | 10.87 | 10.74 | 10.01 | 9.28 | 8.12 | 6.79 | 4.82 | 3.30 | .61 | | | | | | | | | | | |
| 1658 | 15.55 | 11.63 | 11.49 | 10.73 | 10.15 | 8.90 | 7.71 | 5.93 | 4.67 | 2.01 | | | | | | | | | | | |
| 1668 | 16.60 | 12.14 | 12.00 | 11.34 | 10.93 | 9.65 | 8.44 | 7.01 | 5.94 | 3.10 | .18 | | | | | | | | | | |
| 1678 | 17.60 | 12.84 | 12.70 | 12.11 | 11.74 | 10.37 | 9.21 | 7.93 | 7.17 | 4.14 | 1.76 | | | | | | | | | | |
| 1688 | 18.51 | 13.66 | 13.51 | 12.95 | 12.63 | 11.03 | 9.90 | 8.78 | 8.26 | 5.20 | 3.08 | | | | | | | | | | |
| 1698 | 19.30 | 14.57 | 14.20 | 13.71 | 13.41 | 11.63 | 10.62 | 9.59 | 9.21 | 6.36 | 4.24 | .33 | | | | | | | | | |
| 1708 | 20.40 | 15.27 | 14.66 | 14.21 | 14.06 | 12.23 | 11.24 | 10.18 | 9.94 | 7.11 | 5.20 | 1.76 | | | | | | | | | |
| 1718 | 21.69 | 16.21 | 15.17 | 14.79 | 14.67 | 12.95 | 12.00 | 10.93 | 10.67 | 7.97 | 6.18 | 2.84 | | | | | | | | | |
| 1728 | 23.15 | 16.98 | 15.86 | 15.42 | 15.21 | 13.55 | 12.65 | 11.67 | 11.28 | 8.79 | 7.19 | 4.00 | | | | | | | | | |
| 1738 | 24.25 | 17.79 | 16.58 | 16.02 | 15.87 | 14.22 | 13.32 | 12.44 | 11.94 | 9.58 | 8.15 | 5.15 | | | | | | | | | |
| 1748 | 25.12 | 18.33 | 16.55 | 16.37 | 16.29 | 14.84 | 14.04 | 13.20 | 12.41 | 10.20 | 8.75 | 5.96 | 1.06 | | | | | | | | |
| 1758 | 25.78 | 19.01 | 17.37 | 17.00 | 16.67 | 15.28 | 14.48 | 13.72 | 12.86 | 10.75 | 9.46 | 6.76 | 2.08 | | | | | | | | |
| 1768 | 26.52 | 19.98 | 18.10 | 17.49 | 17.24 | 15.76 | 15.01 | 14.25 | 13.40 | 11.29 | 10.08 | 7.47 | 2.86 | | | | | | | | |
| 1778 | 27.24 | 20.86 | 18.79 | 18.06 | 17.80 | 16.30 | 15.60 | 14.85 | 13.83 | 11.80 | 10.65 | 8.03 | 3.38 | | | | | | | | |
| 1788 | 27.68 | 21.61 | 19.33 | 18.66 | 18.25 | 16.73 | 16.04 | 15.42 | 14.17 | 12.36 | 11.15 | 8.48 | 4.00 | | | | | | | | |
| 1798 | 28.03 | 22.08 | 19.75 | 19.09 | 18.59 | 17.09 | 16.41 | 15.79 | 14.56 | 12.85 | 11.67 | 8.89 | 4.51 | | | | | | | | |
| 1808 | 28.67 | 22.55 | 20.10 | 19.40 | 18.94 | 17.38 | 16.81 | 16.22 | 14.90 | 13.31 | 12.14 | 9.36 | 5.03 | .90 | | | | | | | |
| 1818 | 29.35 | 23.13 | 20.55 | 19.87 | 19.31 | 17.70 | 17.16 | 16.68 | 15.26 | 13.87 | 12.65 | 9.85 | 5.46 | 1.81 | | | | | | | |
| 1828 | 29.94 | 23.78 | 20.96 | 20.26 | 19.65 | 18.01 | 17.46 | 16.98 | 15.53 | 14.32 | 13.07 | 10.24 | 5.84 | 2.37 | | | | | | | |
| 1838 | 30.82 | 24.34 | 21.39 | 20.66 | 20.07 | 18.36 | 17.80 | 17.35 | 15.86 | 14.78 | 13.63 | 10.56 | 6.24 | 3.07 | | | | | | | |
| 1848 | 31.46 | 25.02 | 21.84 | 21.11 | 20.48 | 18.73 | 18.23 | 17.67 | 16.18 | 15.19 | 13.88 | 10.94 | 6.73 | 3.58 | .68 | | | | | | |
| 1858 | 31.86 | 25.45 | 22.20 | 21.46 | 20.89 | 19.10 | 18.63 | 18.06 | 16.50 | 15.59 | 14.27 | 11.37 | 7.19 | 4.08 | 1.56 | | | | | | |
| 1868 | 32.25 | 25.84 | 22.45 | 21.71 | 21.17 | 19.51 | 19.09 | 18.45 | 16.90 | 16.08 | 14.77 | 11.78 | 7.56 | 4.48 | 2.06 | | | | | | |
| 1878 | 32.66 | 26.42 | 22.75 | 21.97 | 21.45 | 19.90 | 19.38 | 18.84 | 17.20 | 16.39 | 15.04 | 12.01 | 7.88 | 4.86 | 2.53 | .29 | | | | | |
| 1888 | 33.11 | 27.10 | 23.03 | 22.25 | 21.72 | 20.25 | 19.69 | 19.21 | 17.49 | 16.76 | 15.51 | 12.46 | 8.28 | 5.26 | 2.99 | 1.23 | | | | | |
| 1898 | 33.43 | 27.71 | 23.29 | 22.50 | 21.99 | 20.59 | 20.08 | 19.58 | 17.83 | 17.16 | 15.94 | 12.81 | 8.64 | 5.57 | 3.33 | 1.87 | | | | | |
| 1908 | 33.78 | 28.34 | 23.57 | 22.78 | 22.27 | 20.94 | 20.50 | 19.91 | 18.10 | 17.58 | 16.28 | 13.15 | 9.03 | 5.93 | 3.74 | 2.36 | .32 | | | | |
| 1918 | 34.18 | 28.89 | 24.12 | 23.33 | 22.72 | 21.36 | 20.94 | 20.27 | 18.50 | 18.15 | 16.59 | 13.53 | 9.47 | 6.25 | 4.10 | 2.82 | 1.01 | | | | |
| 1928 | 34.55 | 29.35 | 24.42 | 23.62 | 23.03 | 21.68 | 21.30 | 20.58 | 18.80 | 18.53 | 16.87 | 13.79 | 9.85 | 6.55 | 4.37 | 3.15 | 1.64 | | | | |
| 1938 | 34.98 | 29.88 | 24.86 | 24.03 | 23.42 | 22.13 | 21.62 | 20.89 | 19.15 | 18.96 | 17.17 | 14.08 | 10.24 | 6.83 | 4.68 | 3.44 | 2.04 | .69 | | | |
| 1948 | 35.42 | 30.37 | 25.20 | 24.36 | 23.79 | 22.51 | 21.91 | 21.28 | 19.50 | 19.27 | 17.46 | 14.38 | 10.62 | 7.08 | 4.89 | 3.65 | 2.30 | 1.17 | .28 | | |
| 1958 | 35.69 | 30.91 | 25.60 | 24.75 | 24.09 | 22.93 | 22.27 | 21.59 | 19.75 | 19.53 | 17.76 | 14.71 | 10.93 | 7.36 | 5.09 | 3.80 | 2.43 | 1.36 | .72 | .31 | |
| 1968 | 36.15 | 31.33 | 25.87 | 25.02 | 24.30 | 23.25 | 22.60 | 21.80 | 19.93 | 19.70 | 18.00 | 14.95 | 11.18 | 7.54 | 5.23 | 3.90 | 2.53 | 1.46 | .93 | .58 | |

*Figure 17.--Rescaled radial increment written output.*

# Appendix III

## Stem Analysis Program Listing

```
      PROGRAM NOBLE (INPUT,OUTPUT,PUNCH,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT,
     1TAPE7=PUNCH)
      DIMENSION  HT(31),DIA(31),BT(31),IAGE(31),RADII(80,31),AGAS(31),
     1AGABH(31),HTABH(31),HTTYI(80),IP(31),CRAD(80),RESCL(31,80),IRL(31,
     280),KHT(80),JH(80),JD(80),JB(80)
     3,XAX1(3),XAX2(3),YAX1(3),YAX2(3),BUF(2000),
     4CHT(31)
      DATA  YAX1 /30H HEIGHT  OF SECTION (FEET)      /
      DATA  YAX2 /30H TOTAL HEIGHT OF TREE (FEET)    /
      DATA  XAX1 /30H RADII MEASUREMENTS (INCHES)    /
      DATA  XAX2 /30H AGE AT STUMP   (YEARS)         /
      ISKIP=0
      IF(ISKIP.EQ.1) GO TO 794
      CALL PLOTS(BUF,2000,8)
      CALL SYMBOL (0.,0.,.05,3,0.0,-1)
      CALL PLOT (2.,1.,-3)
  794 CALL ZSUPRS
      CALL FZSUPR
      ISKIP=1
    1 CONTINUE
C
C     READ  "00" CARD
C
      READ(5,1572)IHP,IHT,IHS,IHDBH,JX,IHC,IHSEC,IHAI,YCUT,CRL,Z1,Z2,Z3
     1,Z4,Z5,Z6,Z7,Z8,ELEV,ASP,HSLOP,NLAT,NLONG,PNFSI,NERHT,ISCRD,
     2ISPNT,ISSPT,IHACRD,IHAPNT,IHAPT
 1572 FORMAT(I3,I1,I3,2I4,2I2,I1,F2.0,F2.0,4(A3,A1),F5.0,F2.0,F3.0,2I6,
     1A3,I4,5X,6I1)
      IF(EOF,5)9000,88
   88 CONTINUE
      YYCUT=1900.+YCUT
C
C      ZERO ARRAYS
C
      DO 134 NAO=1,80
      DO 136 NAP=1,31
      HT(NAP)=DIA(NAP)=BT(NAP)=AGAS(NAP)=AGABH(NAP)=HTABH(NAP)=0.
      IAGE(NAP)=IP(NAP)=0
      RADII(NAO,NAP)=RESCL (NAP,NAO)=0.0
      IRL(NAP,NAO)=0
      HTTYI(NAO)=CRAD(NAO)=0.0
      KHT(NAO)=JH(NAO)=JD(NAO)=JB(NAO)=0
  136 CONTINUE
  134 CONTINUE
C
C         READ HEIGHTS OF SECTIONS
C
      READ(5,1000)IPLOT,ITREE,ISP,DBH,IA,ISEC,IAI,(HT(I),I=1,15)
 1000 FORMAT(I3,I1,I3,F4.1,I4,2X,I2,I1,15F4.1)
      IF(ISEC.GT.15)2,3
    2 READ(5,1001)(HT(I),I=16,30)
 1001 FORMAT(20X,15F4.1)
```

```
C
C       READ DIAMETERS OUTSIDE BARK OF SECTIONS
C
    3 READ(5,1002)(DIA(J),J=1,15)
 1002 FORMAT(20X,15F4.2)
      IF(ISEC.GT.15)4,5
    4 READ(5,1002)(DIA(J),J=16,30)
C
C      READ BARK THICKNESS (SINGLE BARK THICKNESS)
C
    5 READ(5,1002)(BT(K),K=1,15)
      IF (ISEC.GT.15)6,7
    6 READ(5,1002)(BT(K),K=16,30)
C
C      READ SECTION RING COUNT
C
    7 READ(5,1003)(IAGE(L),L=1,15)
 1003 FORMAT(20X,15I4)
      IF(ISEC.GT.15)8,9
    8 READ(5,1003)(IAGE(L),L=16,30)
    9 IF(IAI.EQ.1)XINCR=10.
      IF(IAI.EQ.5)XINCR=5.
      IF(IAI.EQ.3)XINCR=1.
      XAGE=IAGE(1)
C
C      READ MEASURED RADII OF SECTIONS
C
      JAC=XAGE/XINCR
      EXST=XAGE-(JAC*XINCR)
      IF(EXST.GT.0)JAC=JAC+1
      JAB=IAGE(16)/XINCR
      EXTRA=IAGE(16)-(JAB*XINCR)
      IF(EXTRA.GT.0)JAB=JAB+1
      NNON=JAC-JAB
      DO 10 M=1,80
      READ(5,1004)CHECK,(RADII(M,N),N=1,15)
 1004 FORMAT(15X,F2.0,3X,15F4.2)
      IF(CHECK.EQ.99.) GO TO 100
      IF(ISEC.GT.15)11,10
   11 IF(M.GT.NNON)71,10
   71 READ(5,1004)CHECK,(RADII(M,N),N=16,30)
      IF(CHECK.EQ.99.) GO TO 100
   10 CONTINUE
C
C      CALCULATE NUMBER OF CARDS
C
  100 CARDS=XAGE/XINCR
      ICARD=CARDS
      XPAGE=IAGE(2)
      CRDS=XPAGE/XINCR
      ICRDS=CRDS
      IF (CRDS-ICRDS)138,138,139
  139 ICRDS=ICRDS+1
  138 IF(CARDS-ICARD)13,13,12
   12 ICARD=ICARD+1
```

```
C
C     CALCULATE  AGE OF TREE AT A GIVEN HEIGHT ABOVE STUMP
C     AND BREAST HEIGHT
C
   13 DO 14 IJ=1,ISEC
      IIJ=IJ+1
      AGAS(IJ)=IAGE(1)-IAGE(IJ)
      AGABH(IJ)=IAGE(2)-IAGE(IIJ)
C
C     CALCULATE HEIGHT ABOVE BREAST HEIGHT
C
      HTABH(IJ)=HT(IIJ)-HT(2)
   14 CONTINUE
C
C      CALCULATE HEIGHTS ABOVE BREAST HEIGHT AT SELECTED YEAR INTERVALS.
C
      NOSEC=1
      IY=XINCR+.05
      NX=IAGE(2)/IY+1
      AXL=NX*IY- IAGE(2)
      IF(AXL.EQ.IY) NX=NX-1
      DO 15 IK=1,NX
      IF(IK.EQ.NX) GO TO 16
      COAGE=XINCR*IK
  784 IF(COAGE.GT.AGABH(NOSEC)) 782,783
  782 NOSEC=NOSEC+1
      GO TO 784
  783 HTINT=HTABH(NOSEC)-HTABH(NOSEC-1)
      AGINT=AGABH(NOSEC)-AGABH(NOSEC-1)
      DIF=COAGE-AGABH(NOSEC-1)
      HTADD=(DIF/AGINT)*HTINT
      HTTYI(IK)=HTABH(NOSEC-1)+HTADD
      GO TO 115
   16 HTTYI(IK)=HTABH(ISEC-1)
  115 KHT(IK)=HTTYI(IK)+.5
   15 CONTINUE
C
C     CALCULATE RESCALE OF RADII FOR INDIVIDUAL SECTIONS
C
      DO 17 ILL=1,ISEC
      IF(ILL.EQ.ISEC) GO TO 17
   20 DO 19 IXD=1,ICARD
      IC=ICARD
      IP(ILL)=ICARD
      CRAD(ILL)=(DIA(ILL)-2.*BT(ILL))/2.
      RESCL(ILL,IXD)=(CRAD(ILL)/RADII(IC,ILL))*RADII(IXD,ILL)
   19 IRL(ILL,IXD)=RESCL(ILL,IXD)*100.+.5
   17 CONTINUE
      IF(IHAPNT.GT.0)GO TO 1601
      WRITE(6,1102)
 1102 FORMAT(1H1,54X,3HCUM/24X,35HC STUMP  B.H.  SITE   HEIGHT   B.H. /
     173H ST PRO  SPE  PLOT TREE T  AGE   AGE   -4.5   -4.5   AGE
     2   CARDS        /  )
 1601 CONTINUE
      DO 23 KIX=1,IC
      MAGE=KIX*XINCR
      IF(MAGE.GT.IAGE(2))MAGE=IAGE(2)
```

```
C
C     PUNCH OUT SITE INDEX CARD
C
      NS=0
      SKKHER=HTTYI(10)
      IF(IAGE(2).LT.100)SKKHER=0.
      KKHER=KHT(10)
      IF(IAGE(2).LT.100)KKHER=0
      IF(IHACRD.GT.0)GO TO 1602
      WRITE(7,1100)NS,ISP,IPLOT,ITREE,IAGE(1),IAGE(2),KKHER,  KHT(KIX),
     1MAGE,ICRDS
 1100 FORMAT(2H 1,2I4,2I3,2H 1,5I4,8X,I3)
 1602 CONTINUE
      IF(IHAPNT.GT.0)GO TO 1603
11015 WRITE(6,1101)NS,ISP,IPLOT,ITREE,IAGE(1),IAGE(2),SKKHER,   HTTYI(KI
     1X),MAGE,ICRDS
 1101 FORMAT(2H 1,4I5,3H  1,I5,I6,2F8.2,I6,8X,I5)
 1603 CONTINUE
      IF(MAGE.EQ.IAGE(2)) GO TO 22
   23 CONTINUE
   22 CONTINUE
C
C     WRITE AND PUNCH OUT INFORMATION ON RESCALE
C
      HERHT=NERHT*.1
      HLONG=NLONG*.1
      HLAT=NLAT*.1
      DHDBH=IHDBH*.1
      ZLONG=NLONG*.001
      ZLAT=NLAT*.001
      JLON=ZLONG
      JLAT=ZLAT
      ZLONG=JLON*100.0
      ZLAT=JLAT*100.0
      ZLATM=HLAT-ZLAT
      ZLONGM=HLONG-ZLONG
      HLAT=JLAT
      HLONG=JLON
      IF(ISPNT.GT.0)GO TO 1604
      WRITE(6,1573)DHDBH,JX,CRLL,Z1,Z2,Z3,Z4,PNFSI,Z5,Z6,Z7,Z8,HERHT,ELE
     1V,ASP,HSLOP,HLAT,ZLATM,HLONG,ZLONGM
 1573 FORMAT(1H1,42X,28HTREE  AND  PLOT  INFORMATION ///5X,4HDBH=,F5.1,
     15X, 9HB.H. AGE=,I4,5X,12HCROWN CLASS=,F3.0,5X,26HHEIGHT TO FIRST L
     2IVE LIMB=,A3,1H.,A1,5X,21HHEIGHT TO LIVE CROWN=,A3,1H.,A1//5X,33HP
     3RELIMINARY NOBLE FIR SITE INDEX=,A3,16X,13HCLEAR LENGTH=,A3,1H.,A1
     4,5X,13HCROWN LENGTH=,A3,1H.,A1,5X,18HTOTAL TREE HEIGHT=,F6.1//
     55X,10HELEVATION=,F5.0,5X,7HASPECT=,F3.0,5X,6HSLOPE=,F4.0,1H%,5X,15
     6HLATITUDE NORTH=,F4.0,4H DEG,F6.1,23H MIN    LONGITUDE WEST=,F4.0,
     74H DEG,F6.1,4H MIN//)
      WRITE(6,1103)ISP,IPLOT,ITREE,(HT(I),I=1,21),(DIA(J),J=1,21),(BT(K)
     1,K=1,21),(IAGE(KRB),KRB=1,21)
 1103 FORMAT(     54X,9HSPECIES =,I4/47X,9HPLOT  NO.,I4,4X,9HTREE  NO.,I3
     1//7X,8HST.HT ++,6X,21HDISTANCE  FROM  STUMP,32X,20HDISTANCE  FROM
     2STUMP/7X,F6.1,1X,20F6.1,1X
     3     /1X,132(1H+)/1X,6HDIA OB,F6.1,1X,20F6.1/1X,6HBARK  ,F6.2,1X,
     420F6.2/1X,132(1H+)/4H AGE,3X,I6,1X,20I6)
```

```
1604 CONTINUE
     JDBH=DBH*10.+.5
     DO 41 IV=1,ISEC
     JH(IV)=HT(IV)*10.+.5
     JD(IV)=DIA(IV)*100.+.5
  41 JB(IV)=BT(IV)*100.+.5
     KNC=1
     KDBH=DBH*10.+.5
     IF(ISCRD.GT.0)GO TO 49
     WRITE(7,1572)IHP,IHT,IHS,IHDBH,JX,IHC,IHSEC,IHAI,YCUT,CR_L,Z1,Z2,Z
    13,Z4,Z5,Z6,Z7,Z8,ELEV,ASP,HSLOP,NLAT,NLONG,PNFSI,NERHT
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JH(KV),KV=1,15)
1105 FORMAT(I3,I1,I3,2I4,2I2,I1,15I4)
     IF(ISEC.GT.15)GO TO 42
     GO TO 43
  42 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JH(KV),KV=16,30
    1)
  43 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JD(KW),KW=1,15)
     IF(ISEC.GT.15) GO TO 44
     GO TO 45
  44 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JD(KW),KW=16,30
    1)
  45 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JB(KX),KX=1,15)
     IF(ISEC.GT.15) GO TO 46
     GO TO 47
  46 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JB(KX),KX=16,30
    1)
  47 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IAGE(KS),KS=1,
    115)
     IF(ISEC.GT.15) GO TO 48
     GO TO 49
  48 KNC=KNC+1
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IAGE(KS),KS=16,
    130)
  49 IAD1=IAGE(1)/XINCR
     LOV=IAGE(1)-(XINCR*IAD1)
     IF(LOV.EQ.0)IAD1=IAD1-1
     IAD2=IAD1
     DO 24 IPOJ=1,ICARD
     IHIST=YYCUT-(IAD1*XINCR)
     IAD1=IAD1-1
     IF(ISFNT.GT.0)GO TO 1605
     WRITE(6,1104)IHIST,(RESCL(IB,IPOJ),IB=1,21)
1104 FORMAT(I5,2X,F6.2,1X,20F6.2)
1605 CONTINUE
     KNC=KNC+1
     IF(KNC.GT.98)KNC=98
     IF(ISCRD.GT.0)GO TO 24
     WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IRL(IG,IPOJ),IG
    1=1,15)
```

```
      IF(ISEC.GT.15) GO TO 51
      GO TO 24
   51 IF(IRL(16,IPOJ).GT.0) GO TO 52
      GO TO 24
   52 KNC=KNC+1
      IF(KNC.GT.98)KNC=98
      WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IRL(IG,IPOJ),IG
     1=16,30)
   24 CONTINUE
      IF(ISEC.GT.21) GO TO 53
      GO TO 8787
   53 CONTINUE
      IF(ISPNT.GT.0)GO TO 8787
      WRITE(6,1107)ISP,IPLOT,ITREE,(HT(I),I=22,30),(DIA(J),J=22,30),(BT(
     1K),K=22,30),(IAGE(KRB),KRB=22,30)
 1107 FORMAT(1H1,53X,9HSPECIES =,I4/47X,9HPLOT  NO.,I4,4X,9HTREE  NO.,I3
     1,4X,9HCONTINUED//13X,21HDISTANCE  FROM  STUMP,32X,21HDISTANCE  FRO
     2M  STUMP/13X,9F6.1/1X, 67(1H+)/1X,6HDIA OB,6X,9F6.1/1X,6HBARK  ,6X
     3,9F6.2/1X,67(1H+)/4H AGE,9X,9I6)
      DO 54 IU=1,ICARD
      IHIST=YYCUT-(IAD2*XINCR)
      IAD2=IAD2-1
      IF(RESCL(22,IU).EQ.0.0) GO TO 54
      WRITE(6,1108)IHIST,(RESCL(JU,IU),JU=22,30)
 1108 FORMAT(I5,8X,9F6.2)
   54 CONTINUE
 8787 CONTINUE
      IF(ISSPT.GT.0)GO TO 1609
      YINK=10.
      IF(IA1.EQ.3)YINK=5.0
      XINK=2.0
      IF(IAI.EQ.3)XINK=1.0
      CALL AXIS(0.0,0.0,YAX1,30,27.5,90.0,0.0,YINK,10.,-1)
      CALL AXIS(0.0,0.0,XAX1,-30,20.0,0.0, 0.0,XINK,20.,-1)
      SPI=ISP
      TREEI=ITREE
      PLOTI=IPLOT
      SSTAGE=IAGE(1)
      CALL SYMBOL(5.0,27.0,.25,12HSTEM PROFILE,0.0,12)
      CALL SYMBOL(5.0,26.5,.25,4HPLOT,0.0,4)
      CALL NUMBER (6.25,26.5,.25,PLOTI,0.0,-1)
      CALL SYMBOL(5.0,26.0,.25,4HTREE,0.0,4)
      CALL NUMBER(6.25,26.0,.25,TREEI,0.0,-1)
      CALL SYMBOL(5.0,25.5,.25,7HSPECIES,0.0,7)
      CALL NUMBER(7.25,25.5,.25,SPI,0.0,-1)
      CALL SYMBOL(5.0,25.0,.25,3HAGE,0.0,3)
      CALL NUMBER(6.25,25.0,.25,SSTAGE,0.0,-1)
      CALL SYMBOL (5.0,24.5,.25,6HBH AGE,0.0,6)
      CALL NUMBER (7.25,24.5,.25,XPAGE,0.0,-1)
```

```
C
C      CALCULATE  HEIGHT  BETWEEN SECTIONS FOR STEM PROFILES
C       AND PLOT STEM PROFILE
C
       DO 445 IHER=1,80
       DO 444 IREX=1,31
       CHT(IREX)=HT(1)+HT(IREX)
       IF(RESCL(1,IHER).EQ.0.0) GO TO 455
       IF(IREX.EQ.1) CHT(1)=HT(1)
       AXISH=CHT(IREX)/YINK
       IF(RESCL(IREX,IHER).LE.0.0)447,448
  447 DIFFA=IAGE(IREX-1)-IAGE(IREX)
       DIFFH=CHT(IREX)-CHT(IREX-1)
       ISA=IAGE(1)/XINCR
       DA=IAGE(1)-(ISA*XINCR)
       IF(DA.EQ.0.0)641,642
  642 SA=DA+(IHER-1)*XINCR
       GO TO 449
  641 SA=(IHER)*XINCR
  449 ANOM=SA-AGAS(IREX-1)
       AXISH=(((ANOM/DIFFA)*DIFFH)+CHT(IREX-1))/YINK
       AXISR=0.0
       CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-2)
       GO TO 445
  448 IF(AXISH.GT.27.5) GO TO 455
       AXISR=RESCL(IREX,IHER)/XINK
       IF (AXISR.GT.20.0) GO TO 455
       IF(IREX.EQ.1) 451,452
  451 CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-1)
       GO TO 444
  452 CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-2)
  444 CONTINUE
  445 CONTINUE
C
C      PLOT  OUT HEIGHT OVER AGE GRAPHS
C
  455 CONTINUE
       CALL  ADVANZ(44)
       CALL    PLOT(0.0,0.0,19)
 1609 CONTINUE
       IF(IHAPT.GT.0)GO TO 1
       YINK=10.
       IF(IAI.EQ.3)YINK=5.0
       XINK=25.0
       IF(IAI.EQ.3)XINK=5.0
       CALL  AXIS(0.0,0.0,YAX2,30, 27.5,90.0,0.0,YINK,10.0,-1)
       CALL AXIS(0.0,0.0,XAX2,-30,21.0, 0.0,0.0,XINK,10.0,-1)
       CALL SYMBOL(5.0,26.5,.25,4HPLOT,0.0,4)
       CALL NUMBER (6.25,26.5,.25,PLOTI,0.0,-1)
       CALL SYMBOL(5.0,26.0,.25,4HTREE,0.0,4)
       CALL NUMBER(6.25,26.0,.25,TREEI,0.0,-1)
       CALL SYMBOL(5.0,25.5,.25,7HSPECIES,0.0,7)
       CALL NUMBER(7.25,25.5,.25,SPI,0.0,-1)
       CALL SYMBOL(5.0,25.0,.25,3HAGE,0.0,3)
       CALL NUMBER(6.25,25.0,.25,SSTAGE,0.0,-1)
```

```
      CALL SYMBOL (5.0,24.5,.25,6HBH AGE,0.0,6)
      CALL NUMBER (7.25,24.5,.25,XPAGE,0.0,-1)
      DO 453 IREG=1,31
      XP=AGAS(IREG)/XINK
      YP=CHT(IREG)/YINK
      IF(AGAS(IREG).GT.525)  GO TO 456
      IF(IAGE(IREG).LE.0.AND.HT(IREG).LE.0.0) GO TO 456
      IF (XP.GT.21.0) GO TO 456
      IF(YP.GT.28.0) GO TO 456
      CALL SYMBOL(XP,YP,.05,3,0.0,-1)
  453 CONTINUE
  456 CALL  ADVANZ(44)
      CALL    PLOT(0.0,0.0,19)
      GO TO 1
 9000 CONTINUE
      CALL PLOT (22.0,0.0,-3)
      CALL PLOT(0,0,999)
  986 STOP
      END
```

Herman, Francis R., Donald J. DeMars, and Robert F. Woollard
1975. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNW-194, 51 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Presents step-by-step instructions for stem analysis field and computer techniques which are adaptable to trees up to 800 years old. Stem profiles, height-age graphs, cards, and data lists are produced by the computer for any conifer for which growth information is to be analyzed.

Keywords: Stem analysis, age determination, ring measurement, data recording methods.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

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